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Does PBL improve student performance in a multidimensional way? A proposal for a moderated mediation model

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Abstract

This paper identifies the profiles of students whose performance is improved by the PBL method, and the influence of certain student-dependent factors that lead to improvement. Effects on performance vary from one student to another, so we distinguish between outcomes among low-performing, average-performing, and high-performing students. To explain the differences in performance improvement among these types of students it is necessary to analyze factors that depend on students themselves. This paper proposes a mediation/moderation model that reveals the influence of prior knowledge, prior motivation, and effort on the performance improvement that PBL brings about among the three types of student. Our findings show that PBL is especially effective among low-performing students, as it results in substantial improvements in their performance levels, making them less dependent on prior knowledge, prior motivation, and the amount of effort made. Performance levels do not improve among high-performing students, for whom obtaining excellent results is observed to depend more on their prior cognitive baggage.

Keywords

Business education, Educational outcomes, Problem-Based Learning, Quantile regression, University

Introduction

Problem-Based Learning (PBL) is a learning method which at first sight seems perfectly adapted to today's business administration requirements (Carriger, 2016). Business problems are often ill-defined and disordered and so lend themselves to a PBL approach (Daly, White, Zisk, & Cavazos, 2012). This paper therefore seeks first to analyze whether performance is improved and if so whether PBL leads to an improvement among students of all types; and second to explain differences according to student-dependent variables.

The purpose of this study is twofold:

1. To identify the student profiles (low-, average-, and high- performing students) for which PBL improves performance. There may be significant differences between the performance levels of students in comparison to the average performance. PBL is associated with specific ways of working that call for specific capabilities or student profiles; this means that its application may have very different outcomes for different students. We seek to use quantile regression to analyze the distribution of performance at different levels or quantiles.
2. To determine whether student-dependent variables can explain differences in performance improvements among low-, average-, and high-performing students. The characteristics of PBL as an active method could explain a general improvement in student performance, but to explain differences in its influence on different student profiles, variables linked to students themselves must be analyzed. Here we propose a mediation/moderation model based on the 3P model by Biggs (1987), which considers students' prior knowledge, motivation, and levels of effort as mediating/moderating variables in the link between PBL and learning outcomes.

Student performance is a multidimensional concept that goes beyond the mere acquisition of academic knowledge. Outcomes should also be assessed in line with two further variables: The

development of skills and capabilities that will be of use to students in their future jobs and their satisfaction with the learning process. In addition, this paper has a third instrumental goal: To adapt the multi-dimensional performance indicator named LEArning-Society-adapted-Outcome (LEASO), as proposed by Fernandez-Sainz, García-Merino, & Urionabarrenetxea (2016), to team performance.

Using quantile regression, we provide evidence that the type of work involved in PBL improves performance among those students who obtain the lowest grades (the bottom 25% of the distribution), without negatively affecting the performance of high-performing students (the top 25%). Moreover, PBL is less affected by other control, mediating, and moderating variables introduced into the regression, such as the prior knowledge and levels of motivation of students. The method is also conducive to consistency in work.

The following section of the paper reviews the PBL method and establishes the links between the method and the performance of students. Next we set out the hypotheses concerned with our objectives and establish a theoretical grounding. Then we explain the method used in our empirical study, defining the population and framework of the sample, the scales of measurement, and the procedures used. After that we present and discuss our main findings. The paper ends with an outline of the main conclusions drawn and the limitations.

Problem-based learning as a teaching/learning method in Business Administration

The goal of PBL is to ensure all-round learning; learning that simultaneously covers the what, how, and why. On the basis of a situation that must be resolved, students come to understand why they learn what they learn. Content and process are considered equally important and the training scenario established is one in which students direct their own learning processes (Zimmerman, 2000).

PBL is one of the most promising active methods in the area of Business Administration and economics in general, thanks to the fact that it explicitly develops knowledge that fits closely

with the demands of business (Carriger, 2016; Mergendoller, Maxwell, & Bellisimo, 2000, 2006; Ungaretti, Thompson, Miller, & Peterson, 2015). Jackson & Chapman (2012) conduct a broad study of university business students in several countries to ascertain what skills are needed in management training, and observe no significant differences in the desired profile from one country to another. The most important skills are problem solving, decision management, working with others, and communication. PBL is a strategy that seeks to strengthen the said competencies and skills (Delaney, Pattinson, McCarthy, & Beecham, 2017; Walker, Leary, Hmelo-Silver, & Ertmer, 2015).

The idea of all-round learning leads to the need to consider a multidimensional concept of performance:

1. Technical knowledge. The advantages of specific knowledge are acknowledged by employees and students alike (Andrews & Higson, 2008)
2. Non-technical knowledge. Studies on the competencies required by the job market show that soft business-related skills or non-technical knowledge are at least as important as hard business-related knowledge or technical knowledge (Tejeiro, Rungo, & Freire, 2013).
3. Satisfaction. Satisfaction is treated as a key outcome in the service sector (Fraser, 1998). There are other determinant factors in student satisfaction, but most studies consider student satisfaction and teaching quality to be related (Gibson, 2010).

This single indicator enables learning outcomes to be analyzed holistically.

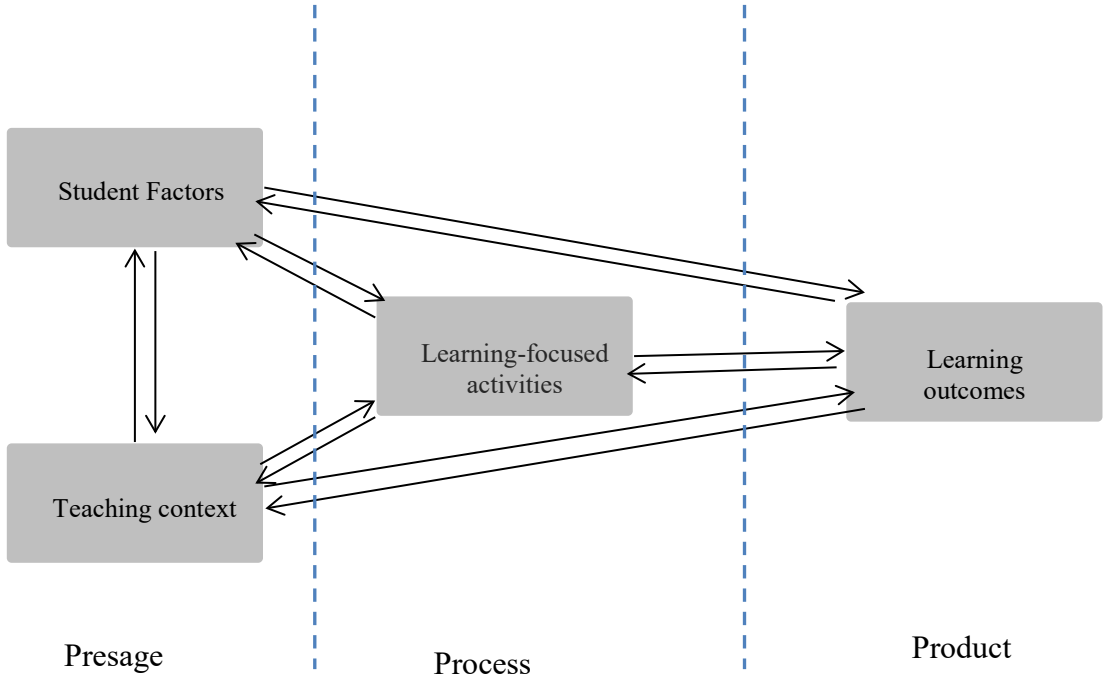
Hypotheses and grounding in theory

The hypotheses put forward here seek to learn whether PBL improves the general performance of students as a result of the characteristics of the method itself, and if so whether the improvements achieved are asymmetrical. Thus, it must be determined what variables associated with students themselves moderate/mediate the link between PBL and performance

so that a discrimination according to profiles can be established. Three moderating variables are proposed (prior knowledge, prior motivation, and effort) and one mediating variable (effort) that could explain such differences.

The 3P model by Biggs (1987) states that the teaching/learning process is structured around three components: Presage-Process-Product (Figure 1). This system is in equilibrium, so a change in any one component will affect the rest (Biggs, Kember, & Leung, 2001). On the basis of this model any change in the teaching method used in order to switch from a conventional method to a PBL method should be reflected in the performance of students. However at the same time it may also be affected by the other dimensions.

Figure 1. The 3P model of teaching and learning



Source: Biggs et al. (2001)

The first hypothesis that this paper seeks is to test whether PBL can have a positive influence on student performance by considering a multidimensional performance indicator. These dimensions may be improved because:

- PBL can make learning more meaningful (Marra, Jonassen, Palmer, & Luft, 2014). Learning is meaningful when its contents are linked substantially to what students already know. PBL needs students to recognize what they already know and what they need to learn in order to solve the problem set, so the integration of knowledge is an essential prerequisite.
- PBL can improve various competencies (Carvalho, 2016):
    - Analytical or problem-solving skills. Learning takes place in small groups which must solve unstructured problems that require use of various information sources. To that end students must follow a logical, analytical approach to decision-making.
    - Promoting creative thinking. Problem-solving encourages students to explore different perspectives, put forward hypotheses, and construct new knowledge.
    - Improvements in cooperation skills. Students work on a collaborative basis, with each contributing his/her own experience and knowledge to help solve the problem.
    - Improvements in communication skills. The need for discussion and debate within working teams reinforces social competencies.
- PBL has a positive influence on the satisfaction levels of students. Active participation in learning is more stimulating than passive transfer of information from the teacher to the learner (Bransford, Brown, & Cocking, 2000).

However, PBL can also entail certain difficulties which may undermine or completely offset its benefits. On the one hand, problem-solving is not necessarily a linear process. This may result in anxiety and a loss of confidence among students (Takahashi & Saito, 2013). Moreover, it is based on collaborative work, so conflicts may arise that hamper its effective implementation.

We believe that the positive effects outweigh the negative ones. This leads to our first hypothesis:

> Hypothesis 1. The outcomes of average-performing students improve when the PBL method is used.

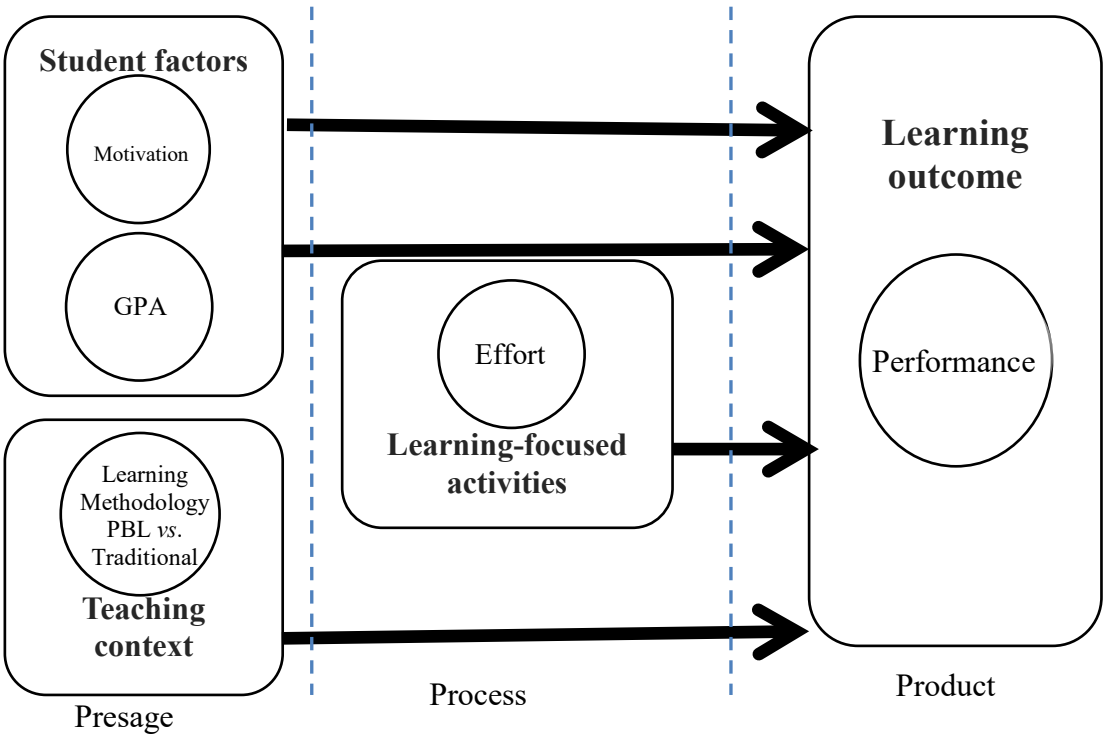
To check out the 3P model it must be taken into account that the *product* (learning outcome) is determined by the *presage* (learning context and factors associated with students) and the *process* (learning approach). Therefore, the rest of the factors in the model need to be monitored.

Regarding *presage*, student factors describe the learning-related characteristics of students in terms of prior abilities, intelligence, personality, and home background (Biggs, 1987). Biggs links these items with two main concepts: The *prior knowledge* and *motivation* of students.

Process includes the activities carried out to bring about this learning. In the case of Spain, business administration students mainly follow the superficial approach to learning, which is conditioned directly by the effort put in by each student (Hernández, García, & Maquilón, 2001).

Figure 2 describes the links between the variables proposed.

Figure 2. Direct link between performance and learning method (Model 1)



However, the results obtained are not homogeneous. The type of students is a potential source of variance (Walker & Leary, 2009). The implementation of PBL may not have the same impact on outcomes for high-performing *students* as for *average-performing* or *low-performing students*.

On the one hand, implementing a PBL method requires students to have skills over and above the ability to memorize data which is key in traditional, reproductive models. In PBL students take an active role (Hmelo-Silver & Barrows, 2006). It is students themselves who must identify their learning needs, seek out the information that they need, and integrate contents to solve problems in a context of constant feedback (Dochy, Segers, Van den Bossche, & Gijbels, 2003). Those students who aspire to be excellent must be so in all these various skills, which is evidently less likely to occur than when excellence is required in memory alone. Downen & Hyde (2016) have found that when the *flipping the classroom* method (the foundations of which are similar to those of PBL) is applied, the biggest improvements are found among students

who formerly showed the lowest levels of performance, while those with higher grades under the old system show no improvement.

On the other hand, working in a PBL mode means working collaboratively, so students can benefit from cooperating with their peers. High-performing students will learn from helping other students and weaker students will learn from their explanations (van der Linden, Erkens, Schmidt, & Renshaw, 2000). However, as pointed out by De Hei, Strijbos, Sjoer, & Admiraal (2015), learning benefits are not distributed evenly throughout the group: previously high-performing members benefit less than medium and low-performing members.

This second hypothesis is therefore put forward:

Hypothesis 2. Improvements in student outcomes are not uniformly distributed.

In line with the 3P learning/teaching model by Biggs, the effects of applying PBL could be influenced by the other two dimensions. We thus consider a mediation/moderation model with prior knowledge and motivation (student factors) as moderator variables and effort (learning-focused activities) as a moderator and mediator variable.

Prior knowledge

Students need to be able to use prior knowledge in novel contexts to solve new problems, answer new questions, and relate what they have learned, i.e. to learn meaningfully. PBL also requires a number of specific competencies such as problem solving, team-working, and communication skills. Students who start out with low skill levels in these competencies are likely to improve most, though some of the abilities involved may be prerequisites for optimizing learning (Carriger, 2016). Mergendoller et al. (2000) observe differences in outcomes depending on students' initial skill levels, and a certain minimum level is needed in order for them to learn effectively (results that are consistent with Vygotsky´s Zone of Proximal Development as Vygotsky (1978) pointed out).

Initial knowledge is usually instrumentalized via Grade Point Average (GPA), though it may give only a limited view of the concept. Carriger (2016) has found that after PBL is applied students with higher initial GPAs improve more in terms of knowledge acquisition than those with lower GPAs. This leads us to the following hypothesis:

> Hypothesis 3a. GPA moderates the relationship between the learning method and performance

Prior motivation

In any learning process students are guided by both intrinsic and extrinsic motivations. Their intrinsic motivation levels can be expected to increase when PBL is implemented. In students for whom this type of motivation is already predominant the marginal effect on performance is lower than among those whose initial levels of intrinsic motivation are low. Wijnia, Loyens, & Derous (2011) find no improvements in performance following the application of PBL among students with predominantly intrinsic motivations.

However, PBL may also act as a trigger for more intrinsically motivated students. Students with predominantly intrinsic motivations may feel that their desire for knowledge is being met and may therefore strive further to find information until their hunger for new information related to the problem is satisfied (Takahashi & Saito, 2013). Mergendoller et al. (2006) record improvements in performance only among the most highly motivated students when PBL was applied.

We therefore put forward the following hypothesis:

> Hypothesis 3b. Prior motivation moderates the relationship between the learning method and performance

Effort

Success in learning certainly depends largely on the effort made by students themselves throughout the process. However, the teaching method applied can affect the level of effort

made by students. There is ample evidence that students work harder when the PBL method is used than with traditional teaching methods (De Graaff & Kolmos, 2003) and greater dedication likely increases learning. Thus, using PBL may have an indirect effect on students' performance to the extent that the effort variable may mediate performance.

Hypothesis 3c. Effort mediates the relationship between the learning method and performance

Effort may be not just a mediating variable for performance put also a moderating variable, as indeed occurs with the other variables.

The time devoted to learning is not the only relevant factor: Discipline and consistency in time spent on learning are also significant (Rau & Durand, 2000). The traditional method requires highly inconsistent levels of effort over the course of the learning process: The major burden of work is in the final stage of the process, when students must sit final exams. With PBL effort levels are more consistent over time (Ramsay & Sorrell, 2007). In short, PBL affects not only the amount of effort made but also the level (or consistency) of that effort.

On the other hand, like most resources, it has a decreasing marginal effect on the performance of students. Those students who habitually make most effort will improve less than those who habitually make less. Moreover, PBL should be more beneficial for the least disciplined, least consistent students.

We therefore consider that the relationship between the teaching method used and the performance of students may be moderated by the effort put in, so:

Hypothesis 3d. Effort moderates the relationship between the learning method and performance

Figure 3. Presentation of a moderated mediation relationship between performance and learning method (Model 2)

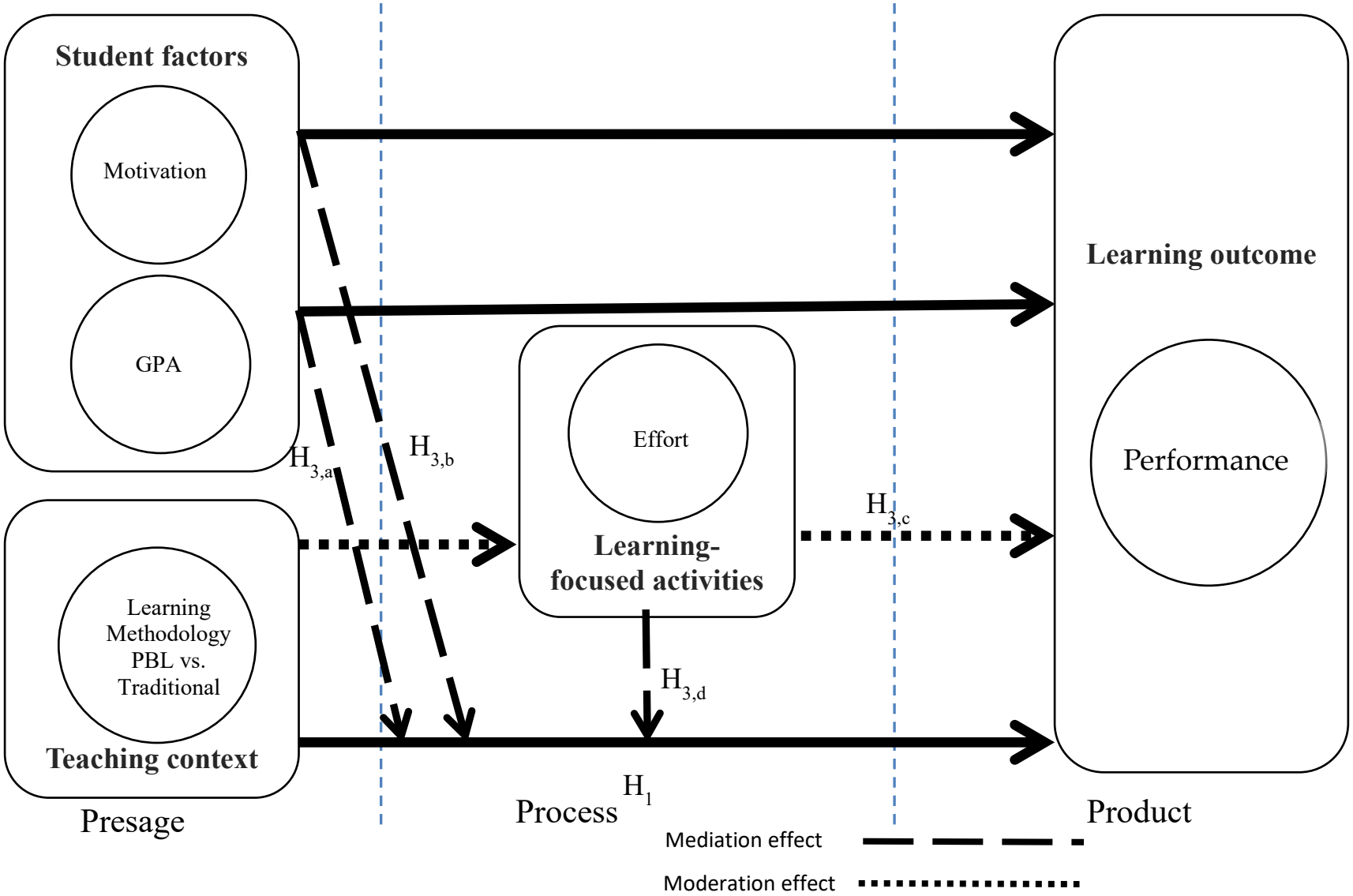


Figure 3 shows a mediation/moderation conceptual model. Mediation analyses focus on estimating the indirect effect of X on Y through an intermediary mediator variable (Me), causally located between X and Y (i.e. a model of the form (X → M → Y). An association between two variables X and Y is said to be moderated when its size or sign depends on a third variable (Mo).

Method

Data and sample

The hypotheses proposed were tested on business administration students at university[1]. The students were split into two groups: One using the traditional teaching method (the Non-PBL Group) and one using PBL (the PBL Group). Students were allocated to the Non-PBL Group or the PBL Group depending on the academic year in which information was collected, as the sample included all the students enrolled in two different calendar years. The teaching staff, curriculum, and learning goals were the same in both groups. They were all third year students on the Business Administration degree. 102 were women (41 Non PBL-Group and 61 PBL Group) and 79 were men (32 Non PBL-Group and 47 PBL Group). All the dimensions required for this study were met in the case of 181 students (73 from the first group and 108 from the second).

Over the first few weeks students were introduced to the basic theoretical concepts; then they were asked to solve an unstructured problem about the financial risks derived from an internationalization decision (they were told the initial situation of the firm and the potential markets) and report their recommendations about that process in groups of four.

Teaching in the academic year of the Non-PBL Group followed traditional methods, with the learning process based on the lecturer as a conveyor of knowledge and formal lectures carried

[1] Information was collected using a self-administered survey that guaranteed the privacy of students and their anonymous, confidential, and voluntary participation. Students were asked for their consent to participate.

considerable weight, though students were required to draw up a portfolio of tasks completed in the course of the year.

Measure of student performance (LEASO). Dependent variable

Students' performance is measured with the LEArning-Society-adapted-Outcome Index (LEASO) drawn up by Fernandez-Sainz et al. (2016), which was designed to analyze the outcomes achieved by students via a holistic approach. This index considers direct (assessment by teaching staff) and indirect measurements (information obtained from students themselves on the degree of learning attained) of students' performance.

The direct measurements are grades awarded by teaching staff. The indirect measurements cover both knowledge (technical/non technical) and satisfaction and are based on students' opinions (Lizzio, Wilson, & Simons, 2002). This information was collected via a questionnaire with a 1-5 Likert scale.

The questionnaire on the knowledge most relevant to the education of business administration students was adapted from Jackson & Chapman (2012). The student satisfaction questionnaire was based on the official student satisfaction survey used by the university. The items referring to the indirect measurement of LEASO coincided with the questions on the survey (Table A1-Appendix A).

A Principal Components Analysis (PCA) was performed to group factors together and thus reduce the size of the dataset. Table A1-Appendix A shows the variables used: knowledge (technical and non-technical), satisfaction, GPA, motivation, and effort obtained from the PCA analysis along with the survey items from which they were obtained. Then a confirmatory analysis was run to check the reliability and validity of the scales of measurement used (Table A2-Appendix A). Taking the PCA into account and giving equal importance to the perspectives of teachers (grades) and students (competencies and satisfaction), the LEASO Index for student "i" was calculated as follows:

$$\text{LEASO}_i = 0{,}5 \times \text{Grade}_i + 0{,}5 \times (k_1 \times \text{Non technical Knowledge}_i + k_2 \times \text{Technical Knowledge}_i + k_3 \times \text{Satisfaction}_i)$$

The k_j terms; j= 1,…,3 are calculated as the proportion of variance explained by each factor.

To assess the effectiveness of PBL, the LEASO is compared to the grades obtained by students (the conventional performance indicator). This makes it possible to assess whether the indirect performance measurements through which the acquisition of non-technical knowledge and student satisfaction are gauged are affected differently from grades.

Measurement of PBL vs Non PBL. Independent variable

The independent variable is a dummy variable that shows membership of the PBL or Non-PBL group.

Control variables and Mediating/Moderating variables

GPA: This was obtained as an average for the sample, based on previous grades in subjects that contained the necessary grounding prior to the one in which PBL was applied.

Motivation: This was built up on the basis of opinions by students as to their initial interest in the course content and their desire to increase their knowledge of that content. The items selected were adapted from an earlier study by Afzal, Ali, Khan, & Hamid (2010). The information was collected via a 1-5 Likert scale.

Effort: This is based on students' answers concerning their dedication to this subject over the course of the academic year (prior to the examination). Opinions were collected via a 1-5 Likert scale. The items were drawn up on the basis of the official survey of student dedication used by the university.

On the basis of students' responses and the PCA, three constructs were drawn up as shown in Table A1-Appendix A.

Econometric method

The various analyses were carried out using both Ordinary Least Square (OLS) and Quantile Regression (QR) methods. QR is a method for estimating the relationships between variables

for all portions of a probability distribution: It seeks the relationship between X and the conditional quantiles of Y $(Q_\tau(Y|X_i) = X_i'\beta(\tau))$, i.e. it extends the ideas of regression to the estimation of conditional quantile functions in which quantiles of the conditional distribution of the response variable are formulated as functions of observed covariates. OLS estimates the conditional mean of the response variable given certain values of the predictor variables, while QR seeks to estimate either the conditional median and/or other quantiles of the response variable. A QR model proposes different regression lines for different levels of the conditional distribution of Y, which we find of interest since the perfomance of students with lower levels of GPA/motivation/effort may not have been comparable to those of students with very high levels of GPA/motivation/effort.

Results and discussion

In line with Hypothesis 1, PBL raises general student performance, as shown by the results of the model estimation using Ordinary Least Squares for both the LEASO Index (Table A3 – Model 1 – OLS) and Grades (Table A4 – Model 1 – OLS).

The improvements in both the LEASO Index and in Final Grades are statistically significant (at 10%) and their effect is positive, so Hypothesis 1 can be considered as validated. Getting students to commit to their own learning processes by presenting a real problem seems to be a good way of improving performance not only from the students' perspective but also as reflected in the grades awarded by teaching staff.

However, in spite of significant improvements in average terms the method does not work in favor of students on all levels of the distribution. There is an asymmetric distribution effect in improvements in outcome (Table A3 – Model 1– QR for LEASO; Table A4 – Model 1– QR for Grades), so Hypothesis 2 is accepted. The marginal influence of PBL on both improvements in LEASO (Figure 4) and grades can be shown (Figure 5). It can be observed that at the lowest levels of the distribution (and approximately as far as the median) the performance of students statistically improves in both the measurements considered. However, the further up one goes the smaller the performance improvement becomes, and there comes a point where there is no improvement at all and, in fact, taking final grades as a proxy, there is actually a drop in performance in the highest percentile (95%) (Figure 4 and Figure 5). These results corroborate the approaches used by Downen & Hyde (2016) and De Hei et al. (2015).

Figure 4. Marginal effect of PBL on LEASO

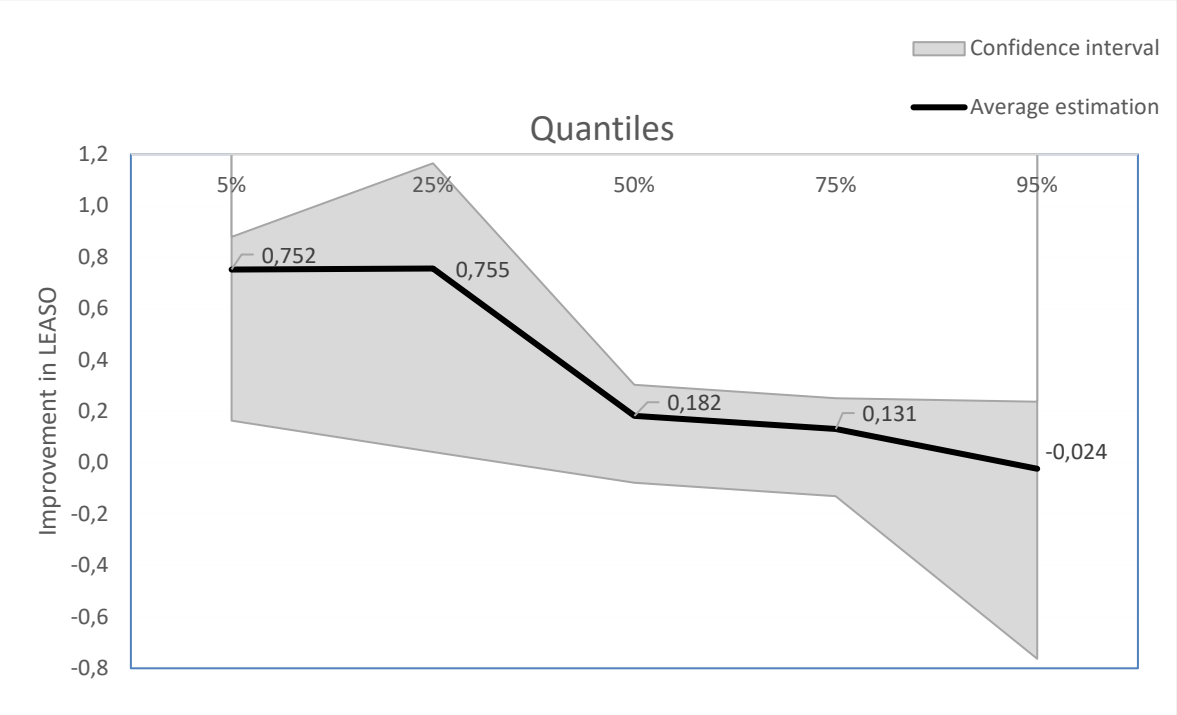
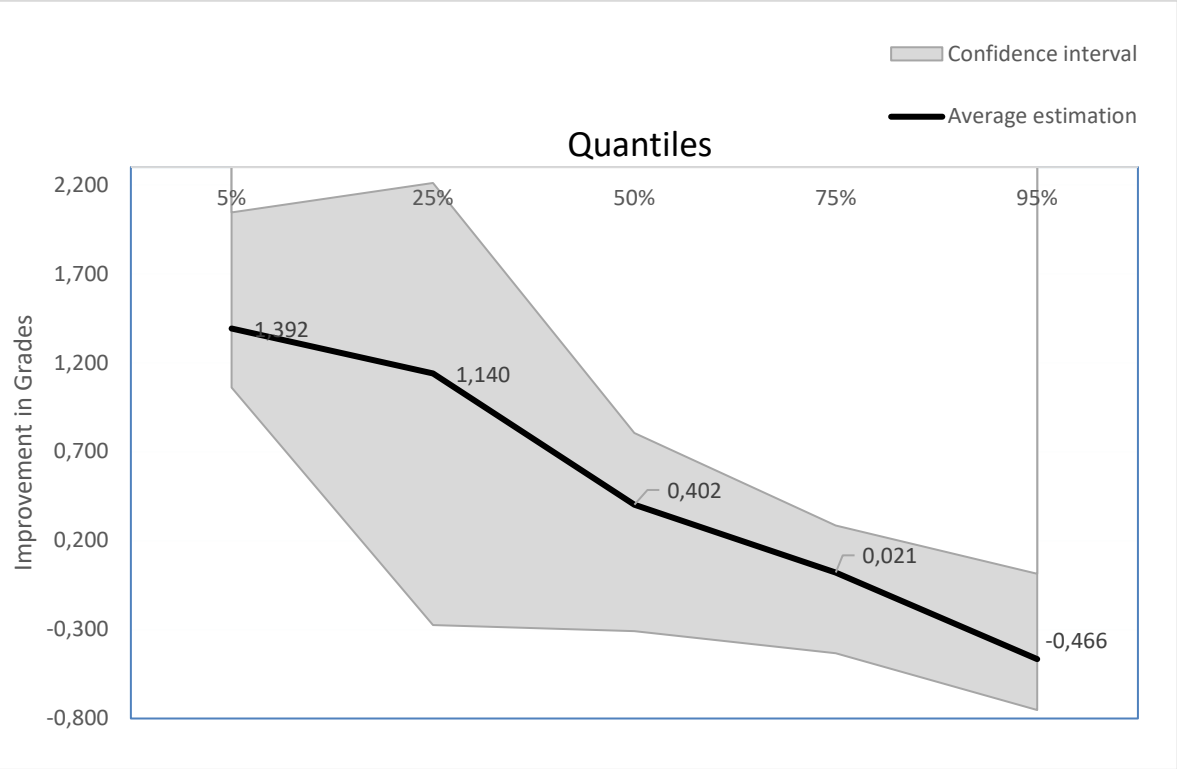


Figure 5. Marginal effect of PBL on Grades



PBL is based on collaborative work, which means that the weaknesses of some team members can be offset by others. *Low-performing* students benefit from collaborating with other students, and this is reflected in their perception of learning and in their final grades. No significant opportunist behavior is found in the group, because the lowest levels of the distribution also show improvements in final exams, which are individual (Figure 4 and Figure 5).

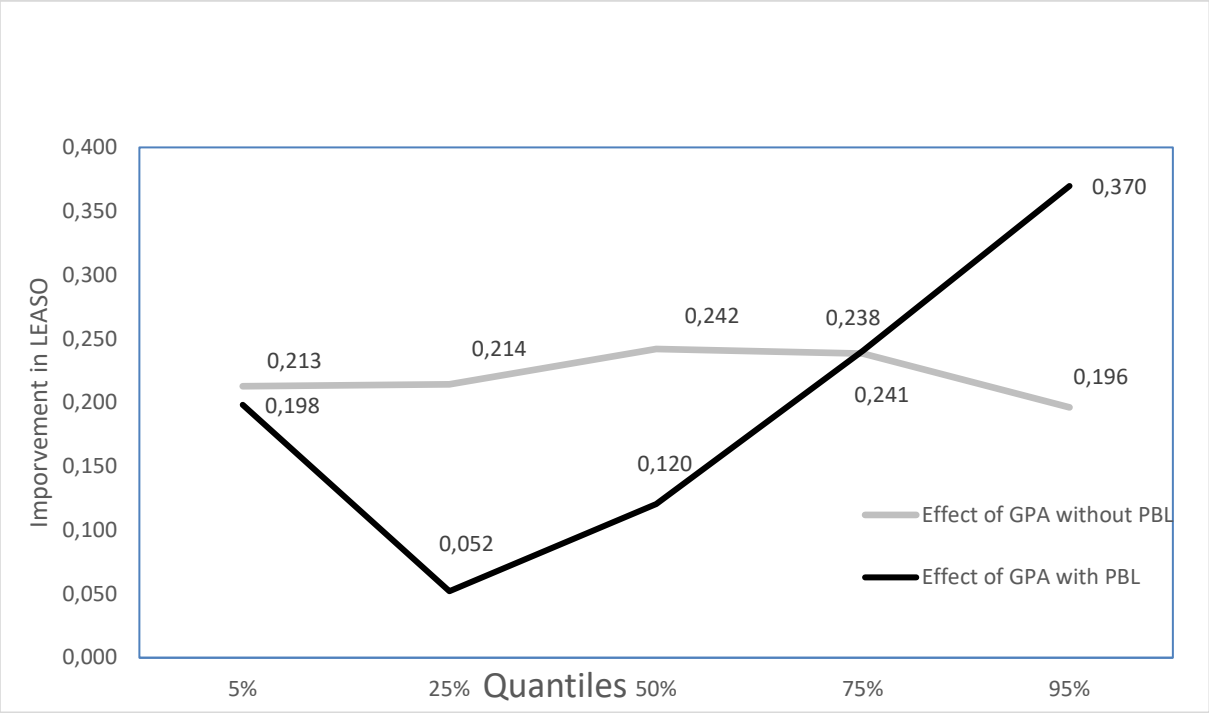
The *high-performing* students obtain lower final grades, but the LEASO Index shows no perception among them that they have learned less. Assessment systems based on final examinations are detrimental to PBL (Biggs, 2011). PBL seeks depth of knowledge over and above broader, declarative knowledge. As far as the LEASO index is concerned, in PBL students have to develop a wide range of competencies. This makes it more difficult for them to attain high performance levels in all competencies (which is why the LEASO does not improve in the top percentiles) (Figure 4). So if the level of the LEASO is

maintained in spite of students obtaining lower final grades (with final grades being one of the components of the LEASO) then there must have been improvements in the perception of their learning processes (the second component of the LEASO).

Differences in performance improvements among high-, average- and low-performing students cannot be explained solely in terms of the characteristics of the learning method: the characteristics of students themselves must also be considered. GPA, motivation, and effort moderate the links between learning methodology and performance in such a way that they explain the differences between the different student profiles. The LEASO Index (Table A3 – Model 2 – QR) and Final Grades (Table A4 – Model 2 – QR) show the same pattern: GPA, motivation and effort are less influential when PBL is applied at the bottom end of the distribution (hypotheses 3a, 3b and 3d –related to moderation effects– are therefore accepted). In general, though not strictly, lower levels of performance are associated with lower levels of GPA, motivation, and effort.

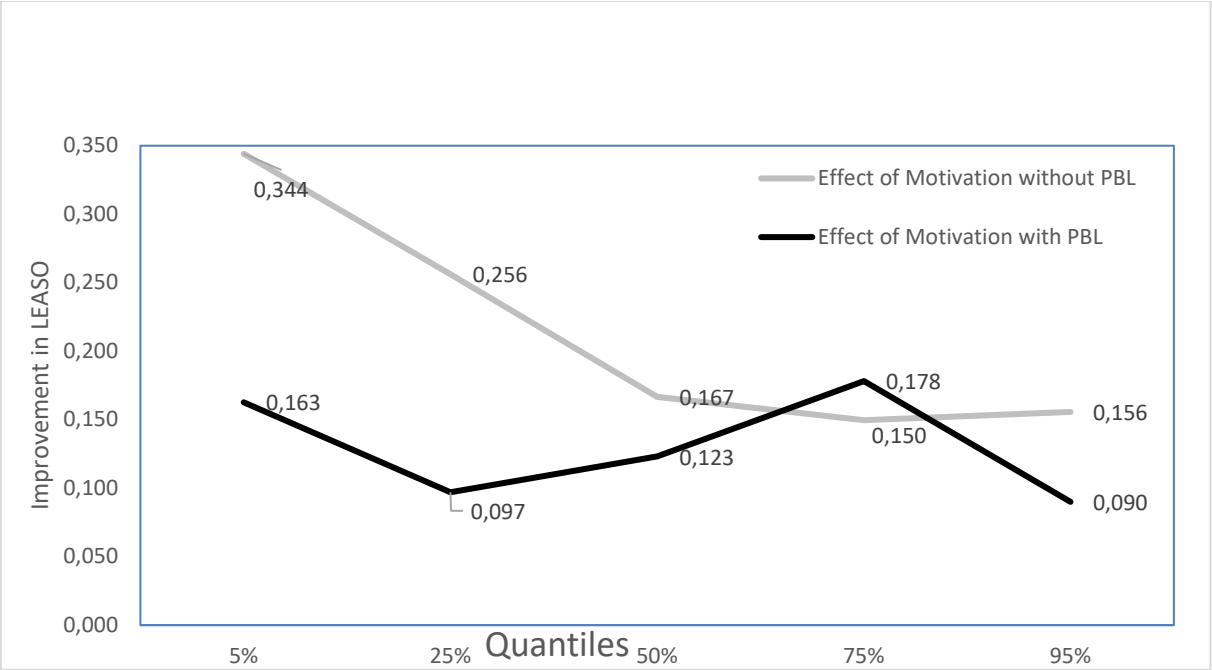
- In regard to GPA, students' prior knowledge is a variable that influences their performance. However, at the lower end of the distribution that influence is lower when PBL is used (Figure 6). This means that the effect of PBL on performance is moderated by GPA. PBL is a form of collaborative work, so students with lower initial capability levels can obtain support from their colleagues and continue their learning processes. The individual capability of each team member is therefore not as important as it is in traditional systems below the median.

Figure 6. Marginal effect of GPA on LEASO



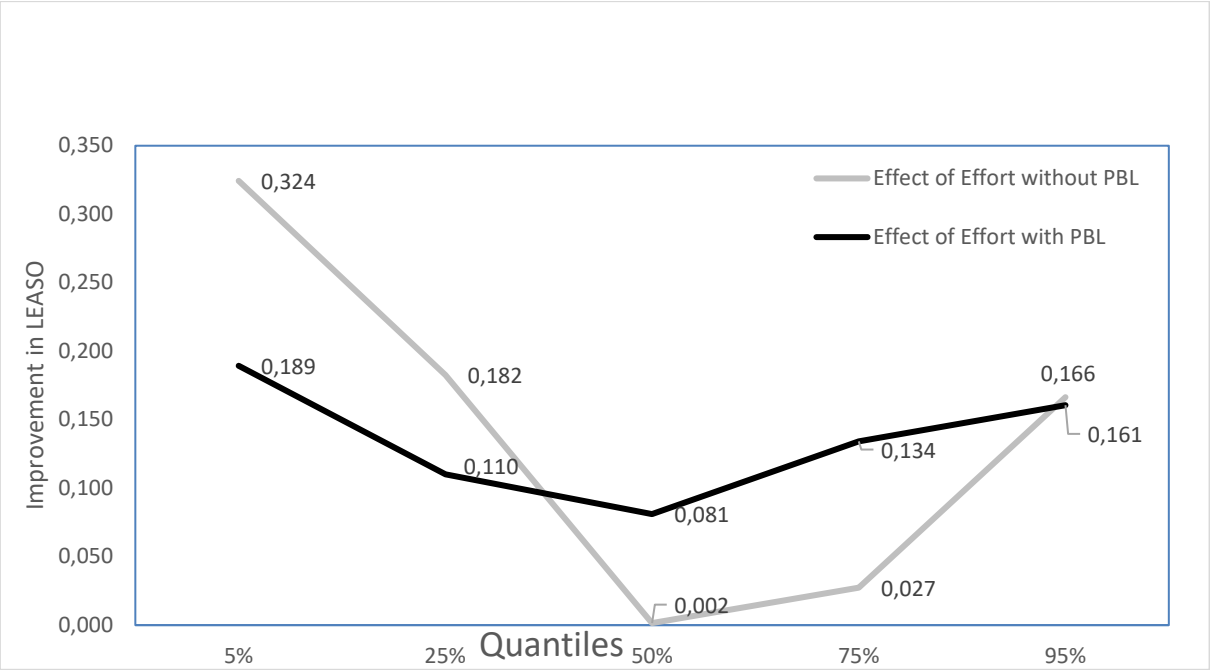
– In regard to motivation, even if students are not initially highly motivated the fact that they are faced with real problems is a motivation in itself, so their initial levels of motivation are less significant (Figure 7). This means that the effect of PBL on performance is moderated by initial motivation for students of this type. However, the benefits in terms of motivation for students who are initially highly motivated are not significant.

Figure 7. Marginal effect of motivation on LEASO



– Finally, in regard to the moderating effect of effort on the relationship between PBL and performance we find, as with GPA and motivation, that effort has significantly less influence at the lower end of the distribution when PBL is implemented (Figure 8). PBL requires dedication over the whole year, so those students who are inclined to make less effort are obliged to work harder. The influence of effort on final performance is therefore lesser, because everyone makes progressive, consistent efforts throughout the semester.

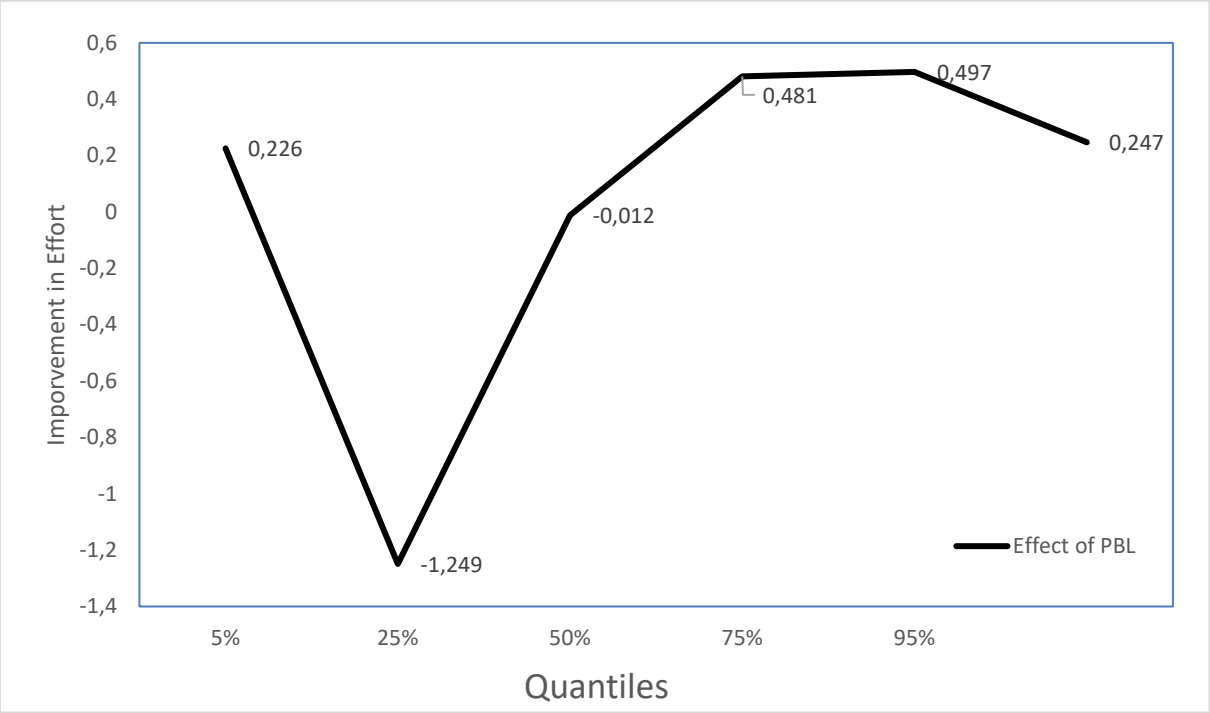
Figure 8. Marginal effect of effort on LEASO



In this study we confirm the suggestion by Biggs (2011) that active teaching methods such as PBL can reduce the gaps between high-performing and low-performing students. PBL enables all students to develop more effective learning strategies that not all of them would otherwise have used.

Moreover, this improvement in performance among low-performing students could be seen as being due to PBL requiring students to make more effort, with effort being a mediating variable between the learning methodology and performance. Our findings show that this is not the case; the improvement in outcomes is attained with no substantial increase in perceived effort levels. As shown in Figure 9, no significant link is found between effort and the PBL method (hypothesis 3c is rejected, Table A5). In other words, the perception of students is that they do not have to make a greater effort. PBL requires consistent effort from the commencement of the year rather than greater effort during interim or final assessment tests (as in traditional methods) (Biggs, 2011). Making consistent efforts may lead students to feel that they are not working more even though they are actually devoting more time to the subject.

Figure 9. OLS and Quantile regression for effort and PBL



Conclusions

This study has analysed the impact of PBL on performance among students with different profiles in Business Administration studies from the viewpoint of a holistic concept of knowledge that includes technical/non-technical knowledge and satisfaction.

PBL works in the same way as the real world: There is a specific problem that students must solve by seeking out the necessary information and tools. That is why PBL fosters the development of a number of competencies that fit closely with job profiles in this knowledge area: Problem solving, decision management, working with others, and communication. Our results confirm this, because average performance improves significantly (i.e. the estimated parametrer of variable PBL is positive, Table A3 Model 1-OLS).

However, PBL leads to different improvements in performance among high-, average- and low-performing students, and is particularly favorable for *low-performing* students.

PBL encourages students to cooperate, which enables *low-performing* individuals to learn from their peers.

Students' performance depends not only on the teaching method but also on other variables such as prior knowledge, motivation, and the efforts that they make during the year. These factors help to explain the differences in performance from one type of student to another. We show that these variables moderate the links between the learning method and performance in a way that explains the differences between the different student profiles. PBL is therefore especially useful in the field of business administration for low-performing students. The performance of these students depends on the prior knowledge, prior motivation, and effort to a lesser extent, because the method itself offsets their potential initial shortcomings. The path that must be taken to solve new problems is not linear, so prior knowledge is not a defining characteristic: Knowledge is used in a different way. The fact that under PBL students must take responsibility for their own learning processes induces a discipline of consistent work, which however is not perceived as a greater workload. The autonomous, collaborative work on real problems required by PBL is motivational for students, so their outcomes depend less on their initial motivation levels.

PBL is therefore especially useful when the students involved do not show high initial levels of knowledge and motivation, and are characterized by inconsistency in effort.

Limitations and future research

The study presented here was conducted with final year business administration and management students at a Spanish university. The results may differ for other types of student, e.g. freshmen or students with different intrinsic motivations and prior knowledge levels. The study therefore needs to be extended to students with different profiles and in different contexts.

Defining the learning context variables other than teaching methods (e.g. the learning climate in the classroom and the assessment system) also affects performance and may help to moderate the relationship between teaching methods and performance. It would be advisable to include further moderating variables in a future study, which we intend to do.

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APPENDIX A

Table A1: Factor loadings and descriptive statistics

	Standardized weights	Mean ±Standard deviation
TECHNICAL KNOWLEDGE (Likert scale: 1- 5)		
TS1: Financial decision-making	0.792	3.42±0.73
TS2: Searching for & analyzing relevant financial information	0.638	3.88±0.70
TS3: Financial problem-solving	0.705	3.52±0.73
NON-TECHNICAL KNOWLEDGE (Likert scale: 1- 5)		
NTS1: Teamwork	0.700	3.72±0.85

NTS2: Autonomous, continuous learning	0.440	3.70±0.81
NTS3: Interpersonal relationship skills (discussion, debate, argument, etc.)	0.751	3.32±0.88
NTS4: Initiative & entrepreneurial spirit	0.653	3.10±0.85
NTS5: Capability for criticism & self-criticism	0.757	3.33±0.89
SATISFACTION (Likert scale: 1- 5)		
S1: Content and subject matter	0.700	3.92±0.80
S2: Teaching method	0.803	4.34±0.64
S3: Assessment system	0.776	4.05±0.73
GRADE (scale: 0- 10)		
Final grade		7.23±1.70
GPA (Likert scale: 1- 5)		
Gr1: Grade in subject 1	0.772	3.84±0.63
Gr2: Grade in subject 2	0.767	3.60±0.79
Gr3: Grade in subject 3	0.637	3.63±0.69
MOTIVATION (Likert scale: 1- 5)		
M1: I find the subject pleasing	0.838	4,30±0.90
M2: I would like to continue learning about the subject	0.905	4.01±0.96
M3: I hope to have a career in this field	0.815	3,63±1.02
M4: I find it easy to learn	0.480	2,97±0.92
EFFORT (Likert scale: 1- 5)		
E1: Class attendance	0.659	4.77±0.56
E2: Degree of involvement	0.828	4.06±0.78
E3: Time dedicated	0.821	3.57±0.96
E4: Total time devoted in relation to estimated time	0.671	3.32±0.95

Note: The Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's sphericity test are statistically significant at 1%. The figures are 0.654 for ‘Technical’ skills, 0.750 for ‘Non-Technical’ skills and 0.679 for Satisfaction

Table A2: Internal validity measures

	Composite reliability	Explained variance	Average variance extracted	Cronbach's alpha
Technical Skills	0.756	61.49	0.5104	0.67
Non-Technical Skills	0.861	47.28	0.4159	0.72
Satisfaction	0.828	57.70	0.579	0.76
GPA	0.294	54.17	0.53	0.77
Motivation	0.419	60.39	0.836	0.76
Effort	0.328	56.11	0.838	0.76

Table A3: OLS and Quantile regression for the LEASO index

	Model 1						Model 2					
	OLS	QR					OLS	QR				
		5%	25%	50%	75%	95%		5%	25%	50%	75%	95%
Constant	3.27**	1.21**	3.40**	4.24**	3.58**	4.21**	3.00**	-0.98*	1.21**	3.87**	4.34**	4.49**
	(6.96)	(3.83)	(6.68)	(14.38)	(10.15)	(18.03)	(4.35)	(1.92)	(3.04)	(5.99)	(7.27)	(5.98)
PBL	0.269†	0.752**	0.755**	0.182†	0.131	-0.024	0.705	2.877**	3.451**	0.659	-0.791	-0.770
	(1.80)	(7.20)	(4.48)	(1.86)	(1.11)	(-0.31)	(0.74)	(7.48)	(6.73)	(0.79)	(1.03)	(0.80)
GPA	0.206**	0.190**	0.139**	0.137**	0.235**	0.297**	0.233**	0.213**	0.214**	0.242**	0.238**	0.196*
	(5.10)	(6.14)	(2.78)	(4.73)	(6.78)	(12.94)	(3.69)	(6.43)	(5.65)	(3.93)	(4.20)	(2.74)
Motivation	0.149**	0.145	0.102**	0.120**	0.184	0.132**	0.189**	0.344**	0.256**	0.167**	0.150**	0.156*
	(3.96)	(5.40)*	(2.35)	(4.78)	(6.13)**	(6.60)	(2.85)	(2.54)	(7.74)	(3.10)	(3.02)	(2.49)
Effort	0.121**	0.206**	0.091*	0.084**	0.108**	0.125*	0.094	0.324**	0.182**	0.001	0.027	0.166*
	(3.06)	(8.28)	(2.27)	(3.59)	(3.88)	(6.79)	(1.51)	(5.94)	(5.48)	(0.03)	(0.55)	(2.65)
PBL-GPA							-0.038	-0.015**	-0.162**	-0.121	0.002	0.174
							(0.47)	(6.43)	(3.26)	(1.50)	(0.03)	(1.85)†
PBL-Motivation							-0.067	-0.181**	-0.159**	-0.043	0.029	-0.066
							(0.85)	(2.54)	(3.68)	(0.62)	(0.44)	(0.80)
PBL-Effort							0.042	-0.135**	-0.072	0.080	0.107†	-0.006
							(0.52)	(5.94)	(1.75)†	(1.18)	(1.72)	(0.07)

Note: t statistics in parentheses; † $p < .1$, *$p < .05$, ** $p< .01$

Table A4: OLS and Quantile regression for Final Grades

	Model 1						Model 2					
	OLS	QR					OLS	QR				
		5%	25%	50%	75%	95%		5%	25%	50%	75%	95%
Constant	1.85*	-1.08*	0.15	2.55**	3.82**	5.54**	0.97	-6.23	-4.02	3.43	4.33	3.01
	(2.55)	(-1.92)	(0.13)	(2.98)	(9.03)	(40.32)	(0.79)	(2.80)**	(2.55)**	(3.36)**	(6.81)**	(3.12)**
PBL	0.475†	1.392**	1.153**	0.402	0.021	-0.466**	1.835	6.688	6.939	-1.058	-0.111	2.088
	(1.81)	(7.48)	(3.05)	(1.41)	(0.15)	(-10.23)	(1.21)	(6.73)**	(6.73)**	(0.79)	(1.03)	(1.03)
GPA	0.091†	0.354**	0.488**	0.458**	0.433**	0.393**	0.490	0.532	0.815	0.466	0.338	0.571
	(1.66)	(6.43)	(4.35)	(5.43)	(10.42)	(29.10)	(4.52)**	(2.52)**	(5.43)**	(4.79)**	(5.59)**	(6.23)**
Motivation	0.480**	0.122**	0.266**	0.222**	0.143**	0.056**	0.278	0.474	0.521	0.151	0.161	0.184
	(8.07)	(2.54)	(2.74)	(3.03)	(3.97)	(4.74)	(2.32)**	(2.57)**	(3.98)**	(1.77)**	(3.05)**	(2.30)**
Effort	0.194**	0.263**	0.096	0.019	0.060†	0.154**	0.129	0.541	0.120	-0.046	0.057	0.224
	(3.03)	(5.94)	(1.06)	(0.28)	(1.81)	(14.21)	(1.16)	(2.91)**	(0.91)	(0.54)	(1.07)	(2.78)**
PBL-GPA							-0.010	0.070	-0.333	-0.007	0.080	-0.185
							(0.08)	(0.25)	(1.69)†	(0.06)	(1.01)	(1.53)
PBL-Motivation							-0.14	-0.457	-0.408	0.071	-0.066	-0.122
							(1.01)	(1.89)†	(2.38)*	(0.64)	(0.95)	(1.16)
PBL-Effort							-0.054	-0.433	-0.118	0.131	0.019	-0.072
							(0.42)	(1.88)†	(0.72)	(1.24)	(0.29)	(0.72)

Note: t statistics in parentheses; † $p < .1$, *$p < .05$, ** $p < .01$

Table A5: OLS and Quantile regression for Effort and PBL

	OLS	5%	25%	50%	75%	95%
Constant	6.16**	3.35**	4.94**	6.15**	7.45**	9.32**
	(27.02)	(4.44)	(14.24)	(23.26)	(25.53)	(51.66)
PBL	0.226	-1.249	-0.012	0.481	0.497	0.247
	(0.70)	(1.40)	(0.03)	(1.38)	(1.29)	(1.04)

Note: t statistics in parentheses; † $p < .1$, *$p < .05$, ** $p < .01$