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Mathematics in economic and business science: how to reach the top without a pathway

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Abstract

The level of mathematical knowledge with which students enter Economics and Business Administration Degrees varies according to the Baccalaureate pathway taken. The Zone of Real Development of students coming from the Social Sciences Baccalaureate differs from the Necessary Zone of Real Development for the correct acquisition of academic competences, which is close to that developed in the Scientific-Technological pathway.

In order to characterise the existing mathematical deficit, a quantitative and perceptive analysis of the mathematical deficiencies of new students in those Degrees coming from the Social Sciences pathway is proposed. The results allow the identification of various areas where training deficiencies exist, which are corroborated by the students' perception.

To solve them, the creation of a virtual platform that identifies, in a personalised way, the deficiencies of each student is proposed. Through guided gamification, the complementary course would allow students to reach the Necessary Real Development Zone before starting University.

Keywords: *Mathematics, economics, business, digital innovation project.*

1. Introduction

The White Paper on the Bachelor's Degree in Economics and Business Administration prepared by the National Agency for Quality Assessment and Accreditation (ANECA, 2005) states that one of the chief problems of the current design of the degrees in this branch is "the inadequate training in mathematics of this Baccalaureate (Social Sciences) compared to that which will be required at the University" due to the existing divergences between the mathematical curricular content of both pathways. Furthermore, it points out that "the content in this subject should be the same as in the Scientific-Technological Baccalaureate".

Although the White Paper was published almost two decades ago, neither successive educational laws nor the adaptation to undergraduate studies that took place with Spain's entry into the European Higher Education Area (EHEA) have managed to solve these deficiencies, making Mathematics one of the most failed subjects in the first year of Economics and Business degrees and, consequently, students have to cope with higher-level subjects (e.g., Economic Analysis, Finance, Statistics, Econometrics) without the required mathematical basis (Anderson et al., 1994; Swope & Schmitt, 2006; Kara et al., 2009).

The mathematical deficit observed can be corroborated in various articles such as Adillón et al. (2013) and Carrillo Fernández et al. (2016), which detail the differences between the mathematical knowledge acquired during the Secondary Education stage depending on the type of Baccalaureate studied. In this regard, articles such as Opstad (2018) show that this is a widespread problem in other European countries, such as Norway, for example.

The main objective of this study is to determine whether the subject of Mathematics taken by students in the Social Sciences pathway of the Spanish Baccalaureate provides an adequate mathematical basis to take and pass the subject of Economics and Business Administration degrees to which it leads, considering the mathematical level with which they enter university and their perception after having taken the university subject.

Therefore, in accordance with Vygotsky (1978), the aim is to characterise the Zone of Real Development (ZRD) of students entering university and to evaluate it with respect to the Necessary Zone of Real Development (NZRD) required for the correct acquisition of university competences, with the purpose of detecting the existence of conceptual deficiencies that prevent the appropriate learning of new knowledge.

2. Methodology

The study consists of two clearly differentiated parts. On the one hand, mathematical aspects are analysed by means of a level test that quantifies the knowledge with which the students of Economics and Business Administration degrees of the Public University of Navarre (UPNA) enter university studies. On the other hand, the perception of the level of

mathematics they have and the demand and adequacy of the level in the Social Sciences pathway of the Spanish Baccalaureate to study university degrees is evaluated.

2.1. Evaluation of mathematical knowledge according to access type

Firstly, an evaluation of the mathematical knowledge acquired by students entering the degrees in Economics and Business Administration during their time in Secondary Education in the Spanish Education System is proposed. To accomplish this, new students were subjected to a compulsory multiple-choice test on the first day of the academic year 2022/23, in order to obtain an objective assessment of the mathematical level with which they access the university and to observe whether this level is sufficient to satisfactorily complete the mathematics subjects of both degrees.

The questionnaire consists of eight control questions, which were used to characterise the entry profile of each student (e.g., access model, Mathematics subject taken in the baccalaureate, average access mark), and eight mathematical questions on various basic aspects of algebra and calculus that should be mastered, as these are the basis for the subjects of both degrees, for instance: a simplification of a radical fraction by means of notable equalities (Q1) or a $2x2$ matrix multiplication (Q8).

2.2. Evaluation of student perception

Secondly, an evaluation of the students' perception of the mathematics subject in the first semester of the Economics and Business Administration degrees is proposed, with the aim of analysing the students' feelings before and during this subject, as well as detecting any possible difficulties encountered.

This information is obtained through the previous survey and with an additional voluntary survey that students can fill out on the virtual platform of the subject from the last day of the semester. On this occasion, the survey consists of fourteen questions, where the first four questions correspond to control questions and the last ten are focused on obtaining the students' perception of the subject, both in relation to the subject taken and to the level of mathematical knowledge with which they have entered the university.

3. Results

In order to carry out the analysis of mathematical knowledge in university entrance and the students' perception, the responses of 299 and 164 students, respectively, are evaluated. Both questionnaires were conducted in an unpaired manner to ensure the anonymous nature of the responses and the difference between the number of responses to the questionnaires is due to the mandatory and voluntary basis of each of them.

3.1. Analysis of mathematical knowledge by access type

As can be seen in *Table 1*, 87% of the people surveyed got five questions or less right, out of the eight questions answered. These results obtained in the initial questionnaire are considerably poor, especially bearing in mind that the eight questions assessed are about basic mathematical concepts that are essential for the correct acquisition of the competences corresponding to university subjects.

Table 1. Distribution of hits in the initial survey.

Number Right Answer	0	1	2	3	4	5	6	7	8
Student Percentage	1%	9%	14%	20%	21%	21%	7%	5%	1%

Analogously, as shown in Figure 1, evaluating the results obtained in each of the questions, only two of the eight answers (Q6 and Q8) are correctly answered by three out of every four students surveyed. In this sense, relevant mathematical deficiencies are found in questions Q2, Q3, Q4, and Q5, as, more than just having a low rate of correct answers (less than 40%), the percentage of wrong answers is higher than the correct answers, which implies that not only have they not acquired this knowledge but also they use it wrongly and based on inadequate mathematical criteria.

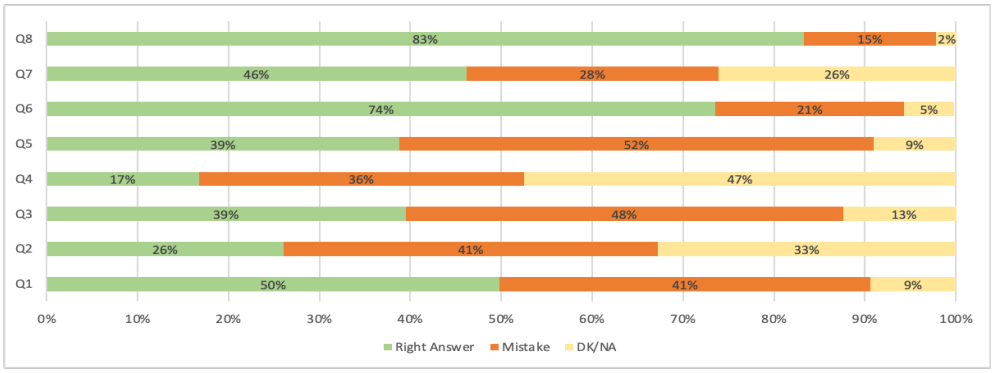

Figure 1. Overall distribution of answers per question.

The lack of mathematical knowledge is more evident when the answers obtained from students coming from the Scientific-Technological Baccalaureate (STB) and the Social Sciences Baccalaureate (SCB) are differentiated, as can be seen in *Figure 2*.

Although it is obvious that students coming from the STB branches have mathematical deficiencies in the knowledge relating to questions Q2 and Q4 (*Figure 3*), they enter with much more complete training and much closer to the minimum knowledge required for the correct acquisition of university contents in those degrees. However, the entry profile of

students coming from the Social Sciences pathway shows highly notable deficiencies in practically all the basic aspects required.

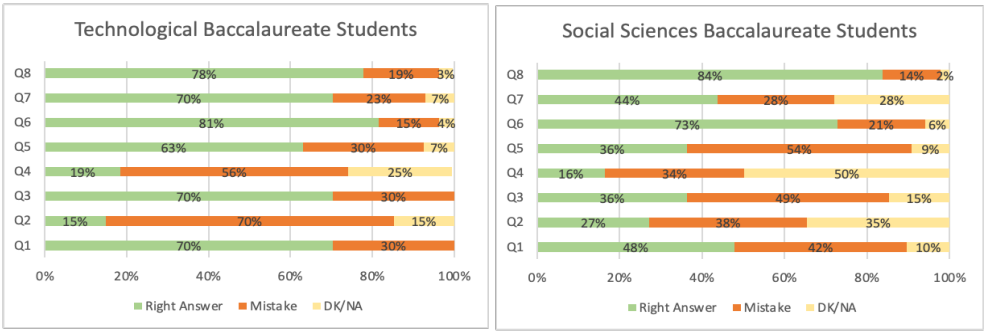

Figure 2. Distribution of answers by question and entry profile.

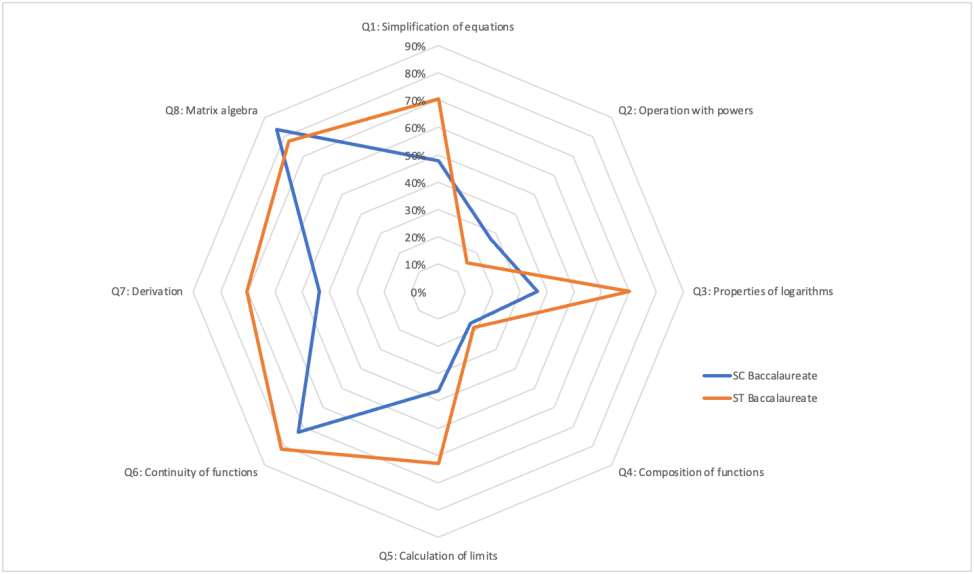

Figure 3. Comparison of mathematical knowledge according to entry profile.

Finally, in order to corroborate that the difference in knowledge between students with different income profiles is statistically significant and that it is not the result of the difference in the number of surveys answered by one group and the other (27 and 272, respectively), a Welch's t-test was performed, with which the hypothesis corresponding to the existence of equality of means between samples can be accepted or rejected; in other words, that mathematical knowledge in both income profiles is identical.

Considering that the *p-value* obtained in the test is 0.00136, lower than the limit marked by the significance level α, the null hypothesis is rejected and the existence of significant differences between the levels of the mathematical knowledge of both profiles is confirmed. Therefore, this result shows that the mathematics of the STB generates more competent and

related profiles than those of the SCB for an adequate understanding of mathematics and the acquisition of the competences of those degrees.

3.2. Analysis of student perception

Student perception is studied, both in relation to their level of knowledge on entering university and in relation to the overall perception of their learning at the end of the Mathematics lessons in the first semester at university, before taking Mathematics exam.

Firstly, analysing the data displayed in *Figure 4*, more than 90% consider their mathematical base to be between adequate and satisfactory. However, these perceptive data contrast completely with the results obtained in the previously analysed questionnaire.

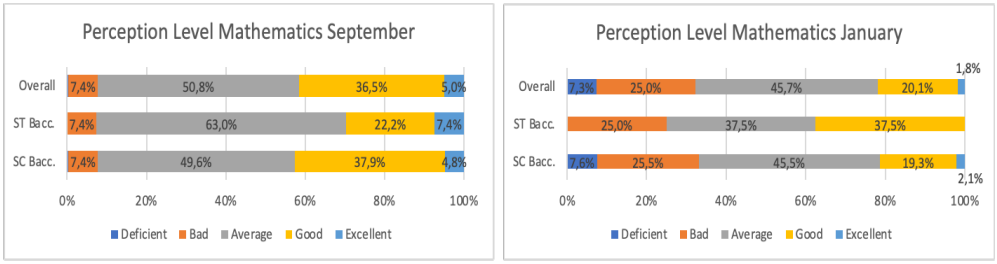

Figure 4. Students' perceptions of their level of mathematics at university entrance.

Nevertheless, at the end of the Mathematics subject, the percentage of students who consider their mathematical base to be between adequate and satisfactory is approximately 30% lower.

In any case, according to the results obtained in the perception survey, there is a large majority of students who consider that they enter university with notable deficiencies in mathematics, as pointed out in *Figure 5*. Students identify the existence of a structural deficit in mathematics training in the Baccalaureate: 69% of them consider that it is essential to improve the level of mathematics in Secondary Education specialisations leading to degrees in Business Administration and Economics and 63% consider that the introduction of a complementary course to cover the shortcomings detected between the exit-level from Secondary Education and the entry-level required for those degrees would be positive.

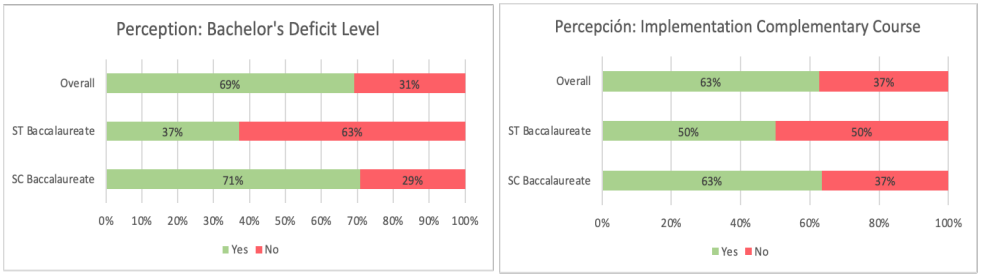

Figure 5. Student Perception of the suitability of access level and the need to implement a complementary course.

In both cases, there is a notable difference in perception depending on the entry profile. While the answers of students who have studied the SCB show a need to improve the level of the Mathematics subject in their speciality and the opinion of implementing the complementary course prevails, with 71% and 63% of positive responses respectively, students in the STB speciality do not consider such a structural deficit in the training received in the mathematics of their speciality nor so essential the implementation of the complementary course.

4. Discussion

The results obtained highlight the existence of significant differences between the level of mathematical knowledge acquired in the STB and that of SCB, in line with previous academic literature (Adillón et al., 2013; Carrillo Fernández et al., 2016). In this sense, the STB provides a considerably more appropriate mathematical basis for entry to Business Administration and Economics degrees, which should not be the case, given that the recommended Baccalaureate for these degrees is that of Social Sciences.

Precisely, students coming from this pathway are aware of the existence of a mathematical deficit in their Baccalaureate modality. This lack of basic training affects all university subjects based on mathematics, as mentioned before (Anderson et al., 1994; Swope & Schmitt, 2006; Kara et al., 2009); thus, corroborating the existence of a difference between the current ZRD and the NZRD (Vigotsky, 1978). In fact, this may be a key reason for the worrying failure and no-show rates in the first year, and even for the high drop-out rates.

This problem is hard to address. The ideal situation for this type of students would be to give them the opportunity to take both SCB and STB Mathematics in the Social Sciences pathway, as a modality and optional subjects, respectively. Unfortunately, this is not possible in most Spanish schools due to organizational reasons. Therefore, the recommended solution to the problem would be to be able to choose STB mathematics as a subject of modality within the Social Sciences pathway, a matter that the current legislation does not consider.

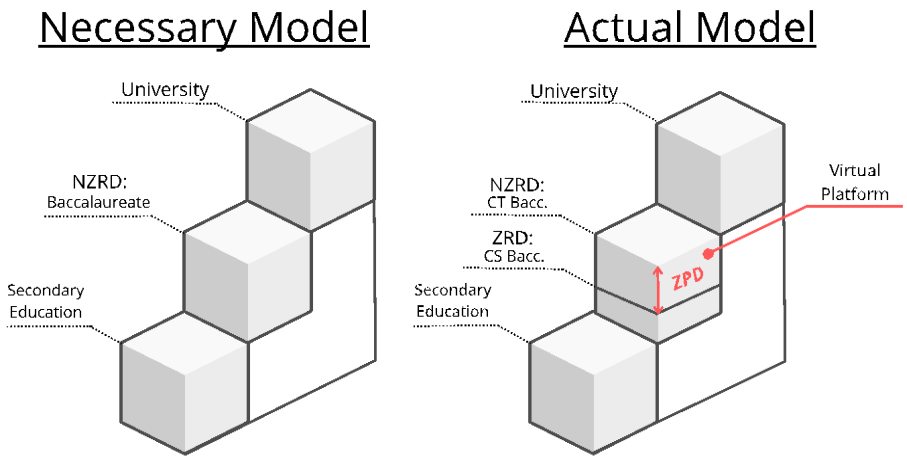

Figure 6. Necessary and current model of the students' Zone of Proximal Development.

Until the education system solves the training problem detected, it is recommended to alleviate this deficit through a virtual platform that allows students to reach the NZRD in a guided manner, prior to the start of the first-year university subjects. In this way, depending on the individual ZRD of each student, characterised progressively as they answer the check questions of each concept to be reinforced in the course, the tool will generate a personalised Zone of Proximal Development (ZPD); that is, an individualised and guided complementary course, which, depending on the deficiencies observed, will lead each student to the target NZRD, as can be seen in *Figure 6*.

This recommendation is in line with what was observed in the carried-out survey: students, especially those coming from the SCB, are clearly in favour of implementing a virtual platform to cover their conceptual deficiencies. The development of this complementary course at the UPNA, which is the next step of current research, is subordinated to the educational innovation project *Digital Gamification to address pre-university mathematical training deficiencies in students of Economics and Business Degrees* of the UPNA.

Finally, note that the study was performed in a single year and exclusively with UPNA students. It would be interesting to carry out this study over a larger number of academic years, as well as in other universities.

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