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Statistical Diagnosis Of Prior Knowledge And The Evolution Of Transdisciplinary Learning Of Natural Sciences In The Degrees In Education

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Abstract

This study consists of a diagnosis of the state of prior knowledge (PC) of two students who enter the Primary Education course (GEP) taught at the King Juan Carlos University (URJC) by means of a series of questionnaires focused on the main disciplines that we traditionally compõem as Natural Sciences: Biology, Geology, Physics and Chemistry. Based on the given nesses, a comparison is made between them and the subsequent academic results (AR) obtained by students after completing the disciplines in the area of Natural Sciences in the GEP. The results show a correlation between the results obtained by the students in the Previous Knowledge Questionnaires (PC) and the academic results (AR). The efficiency rate is 67% for all the disciplines analyzed, which translates into a efficiency rate of 4.5 points in comparison with the PCs. A correlation can be observed for Chemistry, Biology and the general set of Sciences, so that it can be inferred, according to the hypothesis test, which will be the taxa of melhoria two students in these disciplines based on the analysis of their results in CP questionnaires.

Keywords: STEM; prior knowledge; learning outcomes; multidisciplinarity.

1. **Introduction**

A large part of the academic community recognizes the enormous influence that CPs have in the educational context and particularly in relation to Natural

Sciences, which are a core part of the STEM field, on the academic performance of students who study related subjects in the GEP. The importance of prior training in the teaching-learning process has been the subject of multiple studies for decades in very diverse educational settings (Navarro-Medina, 2014 ; Cortés et al., 2015 ; García et al., 2017 ; Brígido et al. (2010) .

From the constructivist theory promoted by Piaget, Vygotsky and Ausubel, it can be stated that "knowledge is not a copy of reality, but rather a construction of the human being that is carried out with the schemes that the person already possesses (prior knowledge). that is, with what it has already built in its relationship with the environment that surrounds it" (Esquivel, 2007). Therefore, we can not only affirm that prior training has an important influence on the learning process, but also the previous ideas and conceptions (whether correct or not) that students have at the beginning of their educational process.

The principles proposed by Ausubel in the theory of meaningful learning establish that in the learning orientation process "it is vitally important to know the cognitive structure of the student; "It is not only about knowing the amount of information he has, but also what concepts and propositions he handles, as well as their degree of stability." (Ausubel, 1983). In order to achieve the so-called meaningful learning, it is essential that the student has the necessary knowledge that lays the foundation from which the new knowledge will be built. In the words of Sangucho and Aillón (2020), sometimes "the student lacks relevant and necessary prior knowledge to make the learning task potentially meaningful." This is well exemplified by the author with the expression "a physical law can be learned significantly without the need to be discovered by the student; it can be heard, understood and used meaningfully, as long as the appropriate prior knowledge exists in its cognitive structure." In this way, it becomes clear that for students to achieve meaningful learning, it is essential to previously analyze what their knowledge is regarding the issue and, consequently, develop a method that allows them to build new knowledge based on their experiences. previous.

Ausubel, 1983) also refers to the need to relate what is going to be learned with what is already known through the connection with the relevant concepts and ideas previously learned by the student. Thus, learning is not carried out mechanically since new concepts obtain meaning and are integrated into the student's cognitive organization. In this way, Ausubel maintains that the best teaching is the meaningful one since it improves and facilitates the retention of the concepts learned, which makes it necessary that there be explanatory materials and that students are predisposed in the teaching-learning process. For their part, Sangucho and Aillón (2020) establish the importance of achieving a balance between the CP and the challenges posed to the student, since if these are not adequately compensated they could make the activity unsatisfactory, generating frustration in learning place.

On the other hand, various authors refer to the so-called negative selection hypothesis (Guarino et al. , 2006 ; Denzler and Wolter, 2009 ; Brand and Xie, 2010 ; Han, 2018). This controversial hypothesis assumes that those students who choose the teaching profession usually have less favorable indices in reference to cognitive variables than those who study other branches of knowledge (Henoch et al., 2014 ; Hanushek and Pace, 1995). This hypothesis could be reflected in the educational profile of students who access the GEP in Spain, where their skills in the STEM field are on average somewhat lower than those of university students as a whole. In this sense, it stands out how in the case of the URJC GEP, more than

75% of the students enter from a specialized baccalaureate in Arts, Humanities or Social Sciences or through other alternative studies such as higher degree training cycles that are related to a lesser extent with the aforementioned area (Melón et al., 2022). Thus, for all Spanish universities, on average, 25.34% of students access the university system through a Scientific-Technological Baccalaureate (Asensio et al., 2022). Also in the study by Asensio et al. (2022) it has been detected that the weighted average in the academic level of entry to the university in the four promotions of teachers between 2014 and 2017 is 5,782 points. This average grade also provides an idea of the low educational level of many of the students who enter the GEP in Spain.

Primary Education (PE) teachers play a decisive role in both transmitting STEM knowledge to students at this stage and stimulating their interest in the disciplines of the field. Various studies show how the loss of scientific vocations, particularly among girls, sometimes occurs in early educational stages, that is, Early Childhood and Primary Education (Chen et al., 2022 ; Martín-Gámez et al., 2018 ; Heaverlo, 2011 ; Zacharia et al., 2020). This could be related, at least in part, to the insufficient suitability of teachers to transmit adequate knowledge and use the available tools to promote meaningful learning of these disciplines in students. In this sense, it is clear how the training that GEP students receive is essential for their future development (Estévez-Mauriz and Baelo, 2021 ; Arabit and Prendes, 2020). Thus, the level of prior knowledge of the students who access the GEP is an indicator of their ability to develop STEM content in the classroom. In fact, Toma and Retana-Alvarado (2021) also point to “the importance of addressing their mental models of STEM education during their initial training,

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establishing spaces for reflection and educational practice that allow them to reconsider their own conceptualizations."

This study aims, in view of all the above, to carry out a statistical diagnosis of the existing relationships between the results obtained by students in the CP questionnaires in comparison with the RAs they achieve in the scientific subjects taught in the GEP at the URJC.

2. Objectives of the study

The general objective pursued by this study is the characterization of the educational level with which students enter the GEP through a series of prior knowledge (PC) questionnaires based on the four major disciplines that make up the so-called experimental sciences. The degree of accuracy in the answers to these CP questionnaires is compared with the academic results (AR) obtained by the students after taking the subjects linked to the field of experimental sciences, allowing the evolution of the students during their time in the GEP to be interpreted. .

The following are pursued as specific objectives:

• Study the differences in the educational level of the participants depending on the different subjects analyzed.

• Establish the general evolution that GEP students follow at the URJC and look for models that allow interpreting the results and trying to understand the causes that produce these behaviors.

3. Methodology

3.1 Sample

In this study, we worked with 310 students, 165 women and 145 men, analyzing the results obtained throughout three consecutive academic years, from 2017-2018 to 2019-2020, corresponding to each course 107, 105 and 98 students, respectively. . As a general rule, the participants have completed the CP questionnaires at the beginning of the third academic year of the degree, with an age between 20 and 30 years, with the median being 21.8 years and the average age being 23.3. years.

3.2 Instrument

The prior knowledge questionnaires have been designed based on schemes similar to those used in the PISA reports, including questions related to the main scientific disciplines (Physics, Chemistry, Biology and Geology). All questionnaires have between 10 and 20 short questions related to the fundamentals of the different subjects. These questions include basic questions such as “Indicate two types of renewable and two non-renewable energy sources”, but also more specialized questions such as “Write the adjusted equation of a chemical reaction that you know”.

In the design of the questionnaires, which have been validated by experts in both the scientific disciplines and the didactics of experimental sciences, the three main types of scientific knowledge have been taken into account, as usually established for this type of tests. assessment:

• Conceptual knowledge. Knowledge of contents related to Experimental Sciences.

• Procedural knowledge. Knowledge of the variety of techniques and practices used to establish scientific knowledge, as well as their model procedures.

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• Epistemic knowledge. Knowledge that is based on how the beliefs we have in Science are the result of understanding the functions of scientific practices, their justifications and the meaning of terms such as theory, hypothesis and observation.

3.3 Procedure and analysis

In this quantitative work, the statistical treatment has been carried out through a correlation analysis between the results of the CP questionnaires and the RA obtained in the subjects of the knowledge area of Didactics of Experimental Sciences taught in the GEP in the URJC.

Data analysis has been carried out using SPSS and Microsoft Excel software tools. A comparative study has been carried out between the CP in natural sciences and the evaluation RA in the related disciplines, looking for possible correlations between both databases.

The variables analyzed are described below:

- Scores on CP questionnaires.
- Scores obtained in the RAs.
- p-values associated with the analysis of each discipline.
- Correlation coefficients.
- Type of model (linear or non-linear)

4. **Results**

The comparison of the data extracted from the responses to the CP and RA questionnaires allows establishing a comparative analysis between them in terms of dispersion and quality of the results. In this way, the degree of competence development between prior knowledge and learning results can be estimated in

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numerical terms, for students who take the GEP in the scientific field in the STEM framework.

Figure 1 presents two box and whisker diagrams with the scores obtained by the students for the set of prior knowledge questionnaires and learning results.

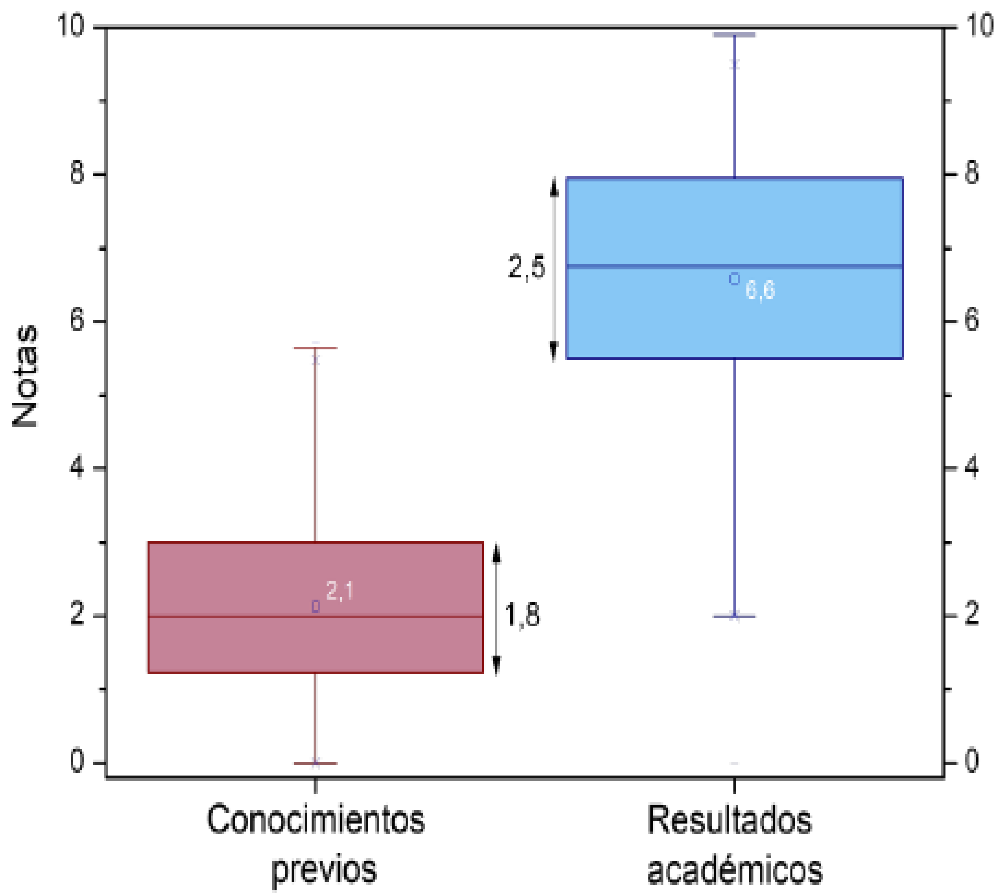

Figure 1. Box and whisker diagrams of the scores obtained in the prior knowledge questionnaires (PC) and the grades corresponding to the academic results (AR) for the group of students object of this study.
Source: self made.

Firstly, it can be seen in Figure 1 that, as a general rule, the overall scores obtained by students in the CP questionnaires for the subjects analyzed are very low, remaining below 3 points out of 10 possible. However, there is a significant increase in the average score obtained when comparing both tests, so that the figure triples, moving its average value from 2.1 points to 6.6. The variability or dispersion of the grades also increases (1.8 to 2.5). Initially, 50% of the grades were between 1 and 3 points, however, the academic results are between 5.5 and 8 points. The interquartile range (IQR) widened by 28% of the initial value.

Taking into account the sex of the students, some slight differences can be seen in the results of the CP questionnaires, as shown in Figure 2. On the other hand, the RAs of both groups are equal in the final tests. The dispersion behavior of the notes is also similar for both sexes. In any case, there is no statistically significant difference either in the scores on the PC questionnaires or, especially, in the final academic results obtained by men and women.

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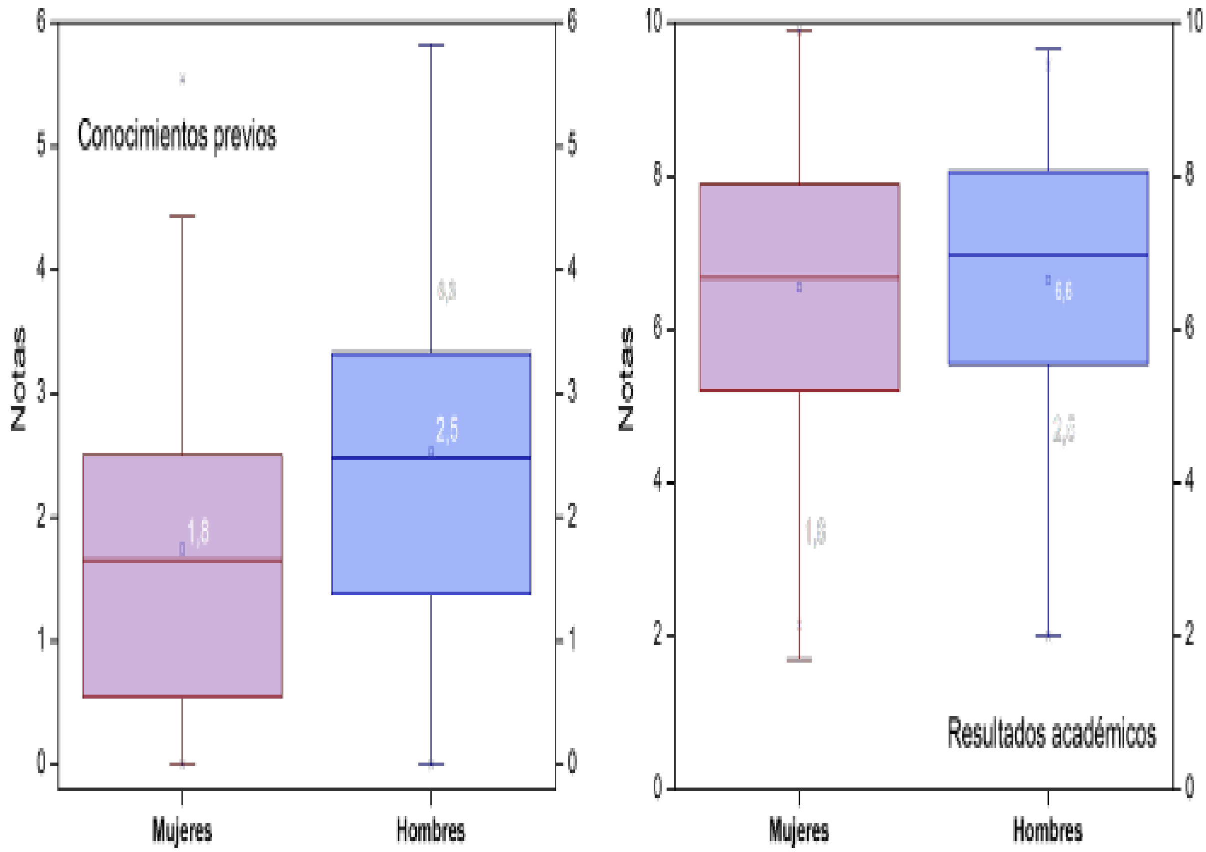

Figure 2. Box and whisker plots for the grades obtained in the Prior Knowledge test and in the Academic Results disaggregated by sex.
Source: self made.

Figure 3 shows through bar diagrams the distribution of the scores obtained both in the CP questionnaires and as extracted from the RAs. It is clearly observed that the behavior of the CP follows a normal distribution where the mean and median are close to 2 points. On the other hand, this distribution disappears for RA, showing an asymmetry biased towards higher values. This asymmetry means that a greater number of students (mode) obtain results above the group median, which in turn is greater than the mean.

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Overall, the shift in the frequency of the data towards higher scores indicates a difference of more than 5 points between the modal and average values when both distributions are compared.

To analyze in more detail the academic evolution of the students, Figure 4 shows the distribution of the final grades that indicate their RA, subordinated or grouped according to the initial score they had obtained in the CP questionnaires.

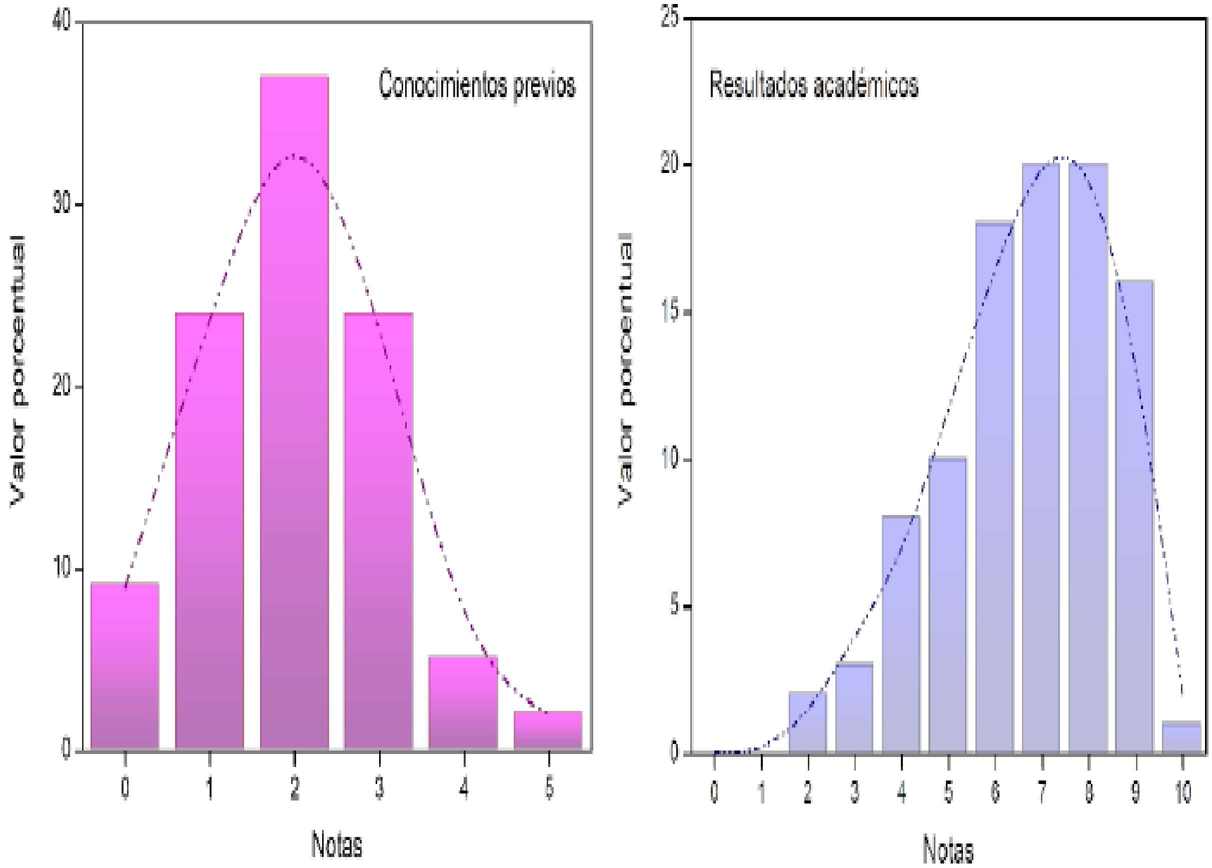

Figure 3. Bar diagrams showing the distribution of the scores obtained in the CP (left) and RA (right) questionnaires.

Source: self made.

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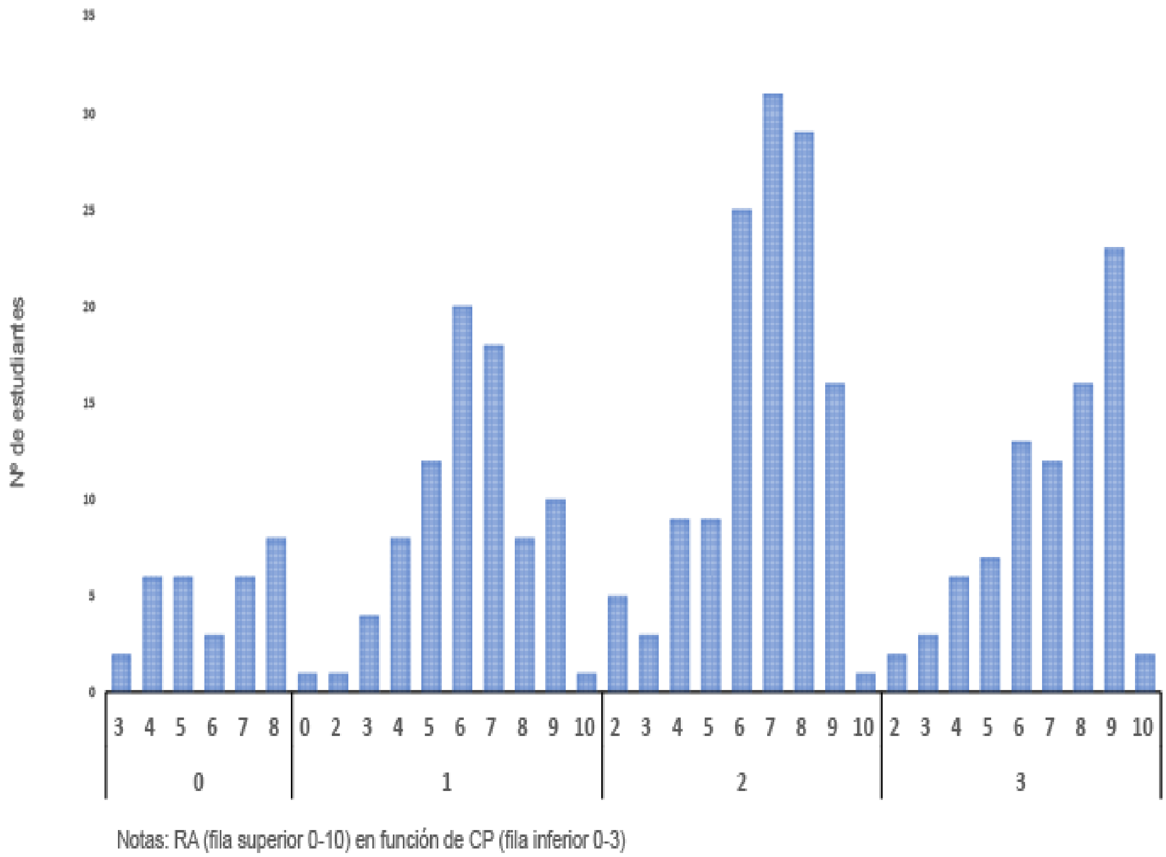

Figure 4. Final grades (RA) grouped according to the initial score (CP). The height of the vertical bars represents the number of students who have obtained each score.

Source: self made.

As the initial score (CP) increases, the frequency distribution profile of the RA experiences a sensitive modification, going from an almost uniform behavior for the lowest score (value 0) to an exponential growth in frequencies for the highest grade (value 3). Specifically, for the series of initial values (0, 1, 2 and 3) the following sequence is seen in the frequency distribution:

uniform ∀ Gaussian ∀ with negative skewness ∀ exponential

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The visible shift of the frequency distributions, which move to the right sequentially with the increase in the grades obtained in the CP questionnaires, shows the profound conditioning that prior knowledge represents in the subsequent academic evolution of the students in terms of subjects related to Natural Sciences.

In order to investigate the possible non-homogeneity of the statistical behavior of the scores of each of the scientific disciplines, firstly Figure 5 shows the disaggregated average scores in the form of a bar diagram. The significant increase that occurs for all the disciplines analyzed when comparing the averages of CP and RA is evident.

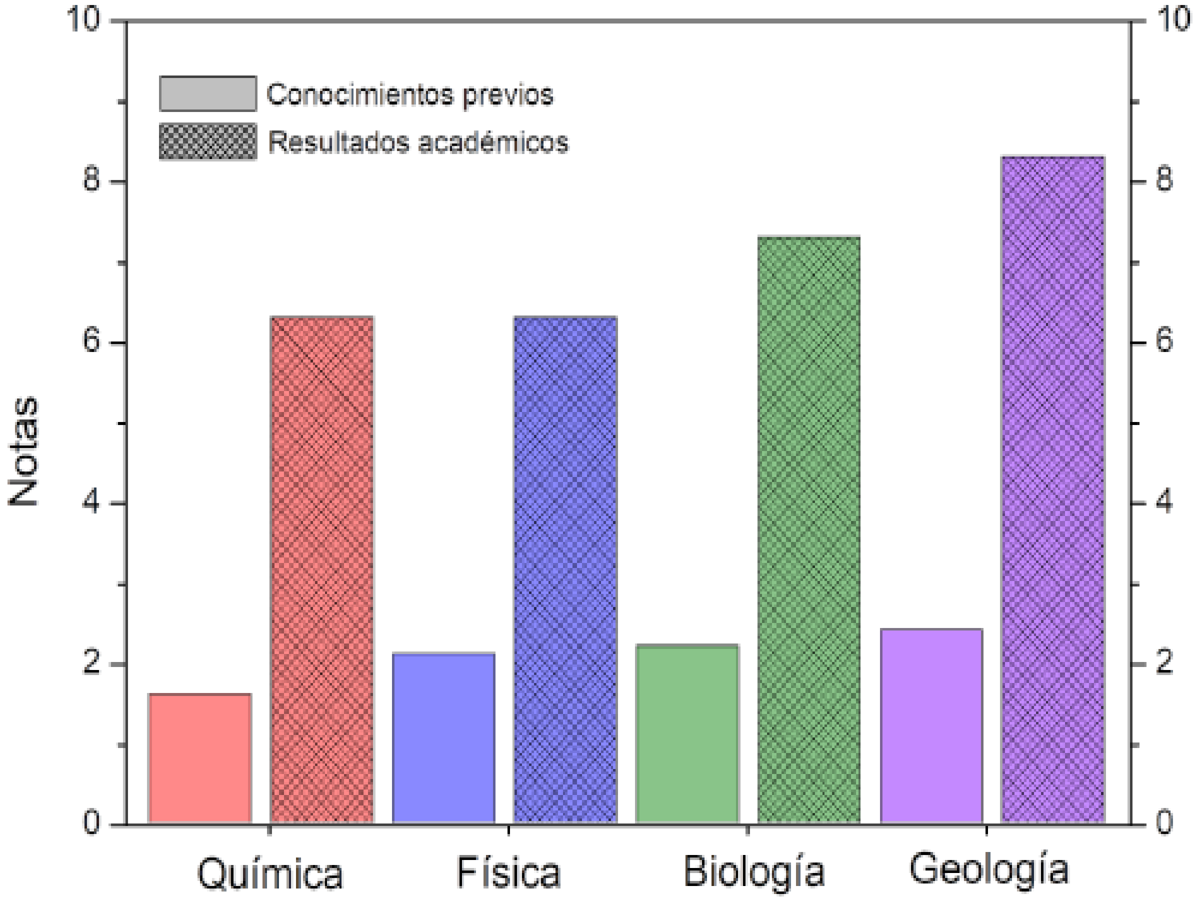

Figure 5. Bar diagrams with the average scores obtained by students in the CP and RA questionnaires disaggregated by scientific disciplines.
Source: self made.

To delve deeper into this analysis by discipline, it is very useful to study the pass rate, which is an interesting variable to describe the overall level of prior knowledge of students of EP degrees. This rate is determined as the percentage of students who obtain at least 5 out of 10 on the CP questionnaire. For Physics, the passing rate is 4.14% and for Biology it is 1.75%. For Chemistry it is 1.63% while in the case of Geology no student passes. These results indicate that students have a very low level of knowledge related to Experimental Sciences and particularly in Chemistry and Geology. However, in this last discipline the greatest difference occurs and, therefore, the greatest rate of improvement in learning of the subjects analyzed.

Regarding the study of the type of distribution of scores broken down by disciplines, Figure 6 uses box and whisker plots, both for CP and RA. Also included are the numerical values that correspond to some of the most common statistical parameters that characterize each of the distributions studied.

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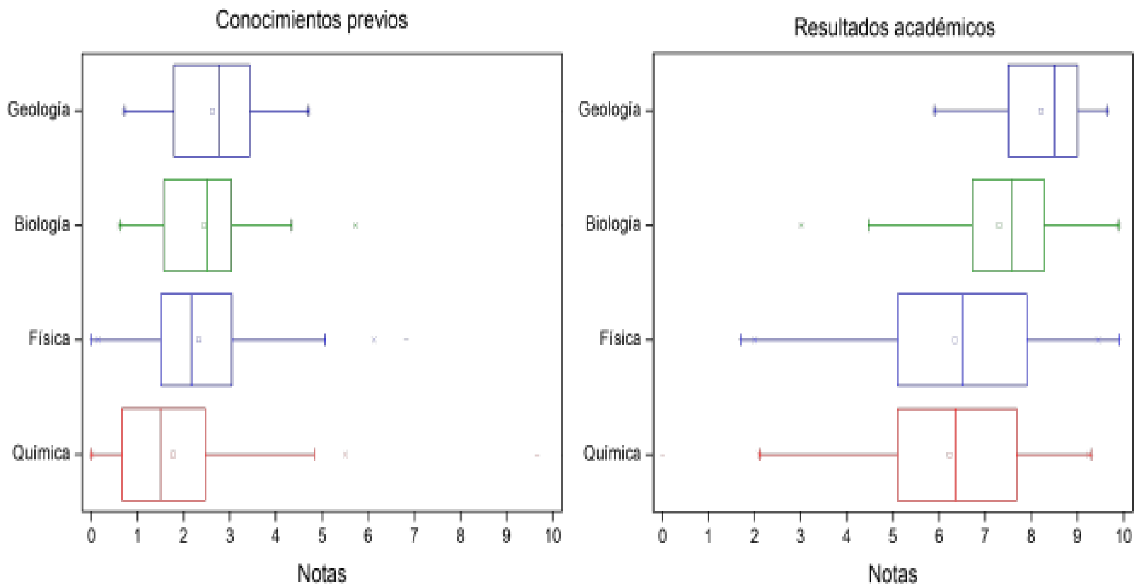

	Q1	Q3	RIC	Mediana	Media
Química	0,66	2,45	1,79	1,49	1,89
Física	1,51	3,05	1,54	2,16	2,28
Biología	1,57	3,03	1,46	2,51	2,44
Geología	1,79	3,43	1,64	2,78	2,61

	Q1	Q3	RIC	Mediana	Media
Química	5,10	7,67	2,57	6,35	6,31
Física	5,10	7,89	2,79	6,50	6,41
Biología	6,72	8,28	1,56	7,59	7,25
Geología	7,49	9,01	1,52	8,51	8,16

Figure 6. Box and whisker plots that represent the behavior of the distributions of CP and RA scores in each of the different disciplines analyzed. The values of the statistical parameters associated with the distributions can be seen in table form below the figure.

Source: self made.

When a multiple range test (MRT) is applied to the variable (CP + subject), it is found that the discipline or subject of Chemistry has a different behavior than the other three, since the multiple comparison clearly identifies two homogeneous groups. The numerical differences observed for the means of intervals obtained have been statistically combined through Fisher's least significant difference (LSD) procedure. However, this same analysis applied to the variable (RA + subject) differentiated up to three homogeneous groups: one common for Physics and Chemistry and another two significantly different ones for Biology and Geology.

It can be stated, therefore, that, despite the unequal behavior of the Chemistry and Physics distributions in the CP scores, the final RAs show a similar behavior. On the contrary, the initial similarity obtained for Biology and Geology finally disappears in the RAs. Figure 7 illustrates this situation by showing the non-homogeneous behavior of the CP distributions in Physics and Chemistry and their subsequent homogeneity in the RAs. In the same way, the homogeneous behavior initially observed in the Biology and Geology group for CP finally disappears in the RA distribution.

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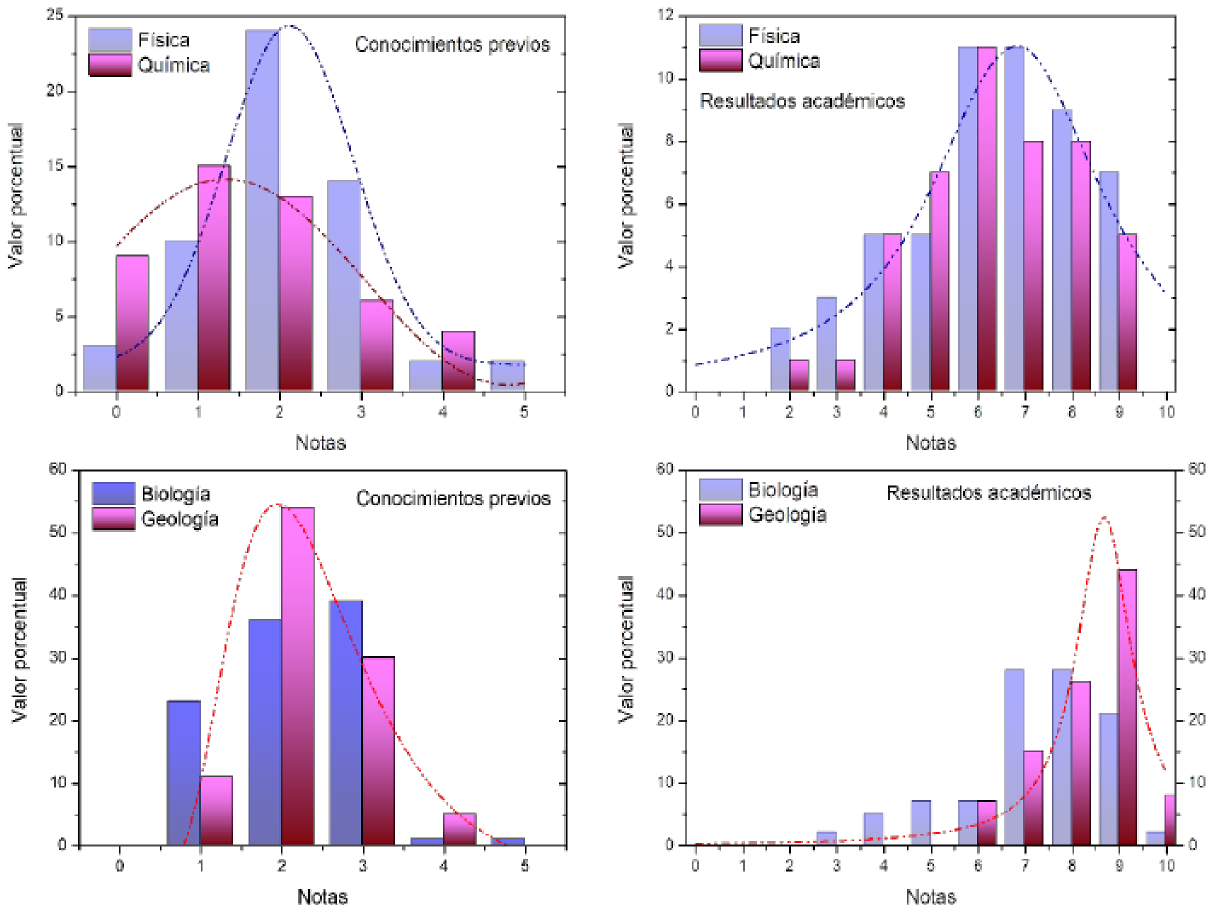

Figures 6 and 7 clearly show that there is no equivalence between the level of students' prior knowledge and their subsequent grades. In fact, the average for the prior knowledge questionnaires is globally 2.1 (out of 10) while the average for the exams is 6.6 (out of 10), reaching an average rate of improvement of about 4.5 points. .

Figure 7. Comparison of the distributions of scores obtained in the prior knowledge questionnaires and academic results. The four disciplines have been grouped in pairs (Physics/Chemistry and Biology/Geology).

Source: self made.

The significant increase in scores is seen individually in each of the disciplines analyzed, although in the case of Biology and especially Geology, the improvement is more pronounced, with the distribution of RA scores being leptokurtic and with negative asymmetry. In comparison, for Physics and Chemistry it can be seen that the distribution is mesokurtic for both disciplines and with a less marked asymmetry. An especially striking aspect of Figure 7 is the change from positively skewed distributions in the CP questionnaires to clearly negatively skewed distributions for the RAs.

To complete the statistical analysis, Table 1 shows the p-values obtained for each of the disciplines studied based on the correlation between the CP and the RA. This statistical variable calculated through hypothesis testing allows us to discern whether the distribution has a statistically representative behavior or if, on the contrary, the distribution is solely the result of chance. In the case of the disciplines analyzed based on the p-value obtained, it can be stated that while in Physics and Geology the results are not statistically representative, in the case of Chemistry, Biology and the Global set for Sciences, The results are representative, always yielding values less than 0.05, which indicate the existence of a significant difference.

Table 1. Analysis of the p-value associated with the correlation between the CP and the RA for each of the disciplines analyzed in the study.

	Chemistry	Physical	biology	geology	Global Sciences
p-value	0.0160	0.1036	0.0093	0.1597	0.0056

Source: self made.

Based on the diagnosis made for these disciplines and as a whole, it is possible to predict the behavior that the groups will have in the future with statistical rigor. This is applicable to the results obtained for the Global Sciences and particularly in the case of Biology and Chemistry.

5. Discussion

Firstly, it is evident that the insufficient prior knowledge and the low level of training in the field of experimental sciences before accessing the GEP determines the academic progress of students in scientific disciplines. For this reason, it is necessary to implement new strategies, tools and methodologies (initiation courses in science and mathematics, new mentions focused on the STEM field, etc.) to improve the level of training that students receive in this field. degrees in EP in Spain and, particularly, in the Community of Madrid.

Although there are multiple reasons why the scores achieved by students in the prior knowledge questionnaires are so low, it seems clear that the fundamental problem is related to the previous training itinerary with which students access the EP degrees, which usually They show poor preparation in science and mathematics. Without a doubt, this is related both to the traditional inclusion of GEP within the field of Social Sciences and to the view that these are teachings aimed at “literary” students.

Although studies such as that of Marchesi et al. 2005 indicate that GEP students feel qualified to assume the future teaching of science at this educational level, other studies (Flores, 1999) already pointed out that this complacency of teachers in training is part of an “unrealistic optimism” that overestimates their teaching abilities. On the other hand, the work of Brígido et al. (2010) also shows that the majority of students prefer the teaching of literature content over science content.

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In this sense, the analysis of the educational profile in science and mathematics of students entering EP degrees can be very useful in three aspects: to reaffirm the poor preparation with which students enter, to help achieve a better understanding of the causes that give rise to the low level of training that they present in these areas and to make the students themselves aware of their shortcomings and of the need they have to be actively involved in the learning process.

On the other hand, this study investigates whether it is possible to establish a prediction regarding the RA that GEP students could hypothetically achieve based on the results obtained in the CP questionnaires. The conclusion is that this hypothesis seems clearly acceptable in the disciplines of Chemistry and Biology and approximately for all sciences (p-value ≤ 0.05). This is of special interest, since it provides a general idea of the increase in performance that students can achieve before having taken any of the subjects related to Natural Sciences. However, in the case of Physics and Geology it is not valid for now to establish a significant statistical correlation (p-value > 0.05) so it would not be possible to predict their behavior based on the results in the questionnaires. CP. As the study will be extended temporally, these predictions will be validated in subsequent courses.

Given the previous training deficiencies of GEP students, the improvement of teaching capabilities in science is intended to modify the structure of degrees at the national level. The workload related to science and mathematics throughout the degree is far from the future teaching demands that primary teachers must face according to the curriculum prescribed by the LOE in its updated version by the LOMLOE (Melón et al . , 2022). Without a profound adaptation of the current design of the degree, it is almost impossible to produce a considerable improvement in the STEM training of future teachers. Another solution proposed for the deficiencies detected is the creation of new "zero courses" at the university level that introduce key concepts in mathematics and science and thus provide the necessary knowledge for future teachers to address the use of the main methodologies. and tools available in the STEM field. In this sense, the proposals of Vidal et al., (2021) focused on the framework of continuous training of Primary Education teachers seem consistent in promoting the exchange of experiences, the analysis and improvement of the resources and methodologies used. in science teaching to ensure that students "learn science by doing science."

There are also other problems linked to the perception of the essence and importance of PE teachers. There is a common idea regarding the social perception of Education at the Spanish and European level. While teachers (at all educational levels) seem to perceive that society does not value them enough, multiple studies such as the TALIS report and the European Mindset report reveal that Education is perceived by society as one of the most (or even the most) important of the professions (Marcelo, 2011 ; Marchesi and Pérez, 2004 ; Marchesi et al. 2005). In any case, this perception is not accompanied by any increase in the investment that states and governments provide for the educational field, relegating the teaching profession to mediocrity. There is no doubt about the importance of increasing investment in education to improve the quality of the training process and, consequently, the teaching-learning process.

In conclusion, it is evident that the training in natural sciences, and more generically STEM, taught in GEP must be significantly improved so that in their future professional activity in the Primary stage, graduates are capable of not only adequately training their students , but also to stimulate their interest in these disciplines, as society demands. In this way, especially in the case of girls, the detachment and even rejection of mathematics and science that is detected from a very early age will be avoided.

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