MATH REQUIREMENTS FOR ADMISSION IN ELEMENTARY SCHOOL TEACHER EDUCATION PROGRAMS: DOES IT MATTER?

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Abstract

In Portugal, the initial training of teachers for the first three levels of education (children from 3 to 12 years old) is carried out through a single 3-years undergraduate degree, called Basic Education. This training is completed with a professional master's degree where future teachers choose which levels they will teach. Most master's degrees cover two levels of education: pre-school and 1st cycle or 1st and 2nd cycles. This means that most teachers become qualified to teach the 1st cycle, usually known as elementary school. First cycle teachers teach all educational areas, including mathematics. It is, therefore, essential that they finish their degree in Basic Education with a solid background in Mathematics.

Until the academic year 2017-18 there was no mandatory entry requirement in Mathematics to the Basic Education Degree and many students were admitted without having had any Mathematics in secondary education. To ensure a better pre-university training in Mathematics, the Portuguese government imposed an admission exam, as from the academic year 2018-19.

This work aims to assess the impact of the government measure on the training of future teachers in the area of mathematics, through the analysis of the performance of students in the 1st year of the Basic Education Degree, from a Portuguese university, in a mathematics course of the 1st semester, over the academic years 2017-18 to 2019-20. The statistical study carried out reveals that there were significant improvements in the results of the students.

An analysis of the gender tendency in the choice of the teaching profession was also done and showed that there is a disproportion between men and women in pre-service teachers, since most young people who want to become teachers are female.

This study contributes to a better understanding of the impact certain measures and policies can have on the quality of Higher Education academic training. This type of approach can be applied to other similar situations, for other programs and other courses, helping, in this way, decision making in Higher Education admission policies, as well as researchers in this field.

Keywords: Entry requirements for higher education, pre-service teacher education, math skills, student performance, hypothesis testing.

1 INTRODUCTION

During the first decade of the XXI century a Europe wide reform of higher education systems was undertaken to homogenize the systems across all Europe. This reform is known as the Bologna process, and in Portugal it led to a reorganization of the system of degrees and diplomas in higher education legislated through the law [1].

Teacher training, as many other degrees, was reformulated, becoming bi-phased, with an initial undergraduate degree of 3 years followed by a post-graduate professional master lasting 3 or 4 semesters.

In Portugal, pre-university education is organized into five levels: pre-school (children from 3 to 6 years old); 1st cycle of basic education (four years of schooling for children aged 6 to 10); 2nd cycle of basic education (two years of schooling for children aged 10 to 12); 3rd cycle of basic education (three years of schooling, ages of 12 to 15); and secondary education (three years of schooling, ages 15 to 18).

The initial training of pre-service teachers of the first three levels of education is carried out through a single degree, at national level, the undergraduate degree called Basic Education Degree (BED), established through national legislation [2], following the reformulation of the system of degrees and diplomas mentioned above.

Since its creation, the conditions of admission to this course have been determined by each institution of higher education, and it is up to them to indicate which entrance exams are required. Many institutions did not require their candidates to do any mathematics exam. Experience has shown that a significant part of the students entered this degree without having had mathematics in secondary education, presenting serious gaps that are very difficult to overcome during graduation. The Portuguese government recognized the risks that such a situation entailed and imposed, through legislation [3], an admission exam in mathematics to BED, which came into force as of the academic year 2018-19.

The aim of this work is to investigate whether the measure adopted by the government had consequences on the performance of pre-service teachers in mathematics. For this purpose, it was decided to compare the performance of students in the 1st year of the BED, from a Portuguese university, in a mathematics course of the 1st semester, before and after the introduction of the measure.

At the same time and motivated by the fact that there is a systematic predominance of female students in the BED, the proportion of men was statistically analysed.

The issues that this work addresses, can be included in a vaster set of problems where it is important to compare performance indicators in order to analyse the impact of specific actions/changes in various types of areas. Looking at more recently published work, there are several examples of the application of statistical techniques to address such problems.

In [4], [5] and [6] situations regarding training and teaching outcomes are presented. In [4] students' grades, the same outcome that is analysed in this paper, are studied in order to understand if the use of Moodle tests or Socrative quizzes had a positive impact in students' performance when compared with the traditional method. In [5] the topic studied was firefighters training and ANOVA and t-tests were used to determine if hazard recognition training had affected firefighters hazard recognition performance. In that case t-tests were used to compare the performance of a group of firefighters immediately after the training and 3 months afterwards. In [6] the impact of an educational physical activity intervention directed at bus drivers was analysed and, using t-tests, it was possible to assess that the activity had a positive effect on the prevention of musculoskeletal disorders in those professionals.

These techniques are also frequently employed in the materials area. In [7] the authors used one-way ANOVA to compare some physical characteristics (e.g. tensile strength, tearing strength) of non-woven fabrics produced from recycled materials, for different production parameters. In [8] the fracture resistance of materials used in dental treatments was compared and three factors were considered: type of material, thickness of the material and the storage system.

Another common use of these techniques is in health studies such as the ones presented in [9] and [10]. In the first situation, t-tests were used to study if the use of MR imaging referral by general practitioners was cost-effective in patients with traumatic knee symptoms, by looking at healthcare costs and health outcomes. In [10] the authors describe a clinical trial to compare two drugs used for treatment of pain and depression in women with fibromyalgia where they apply t-tests.

Besides the previous explained areas, it is also possible to find this type of studies in a very diverse number of sectors like, for example, building maintenance [11], laboratory sample preparation [12] and the influence of the type of bait used on eel fishing [13].

The usefulness of these statistical approaches is, therefore, well documented and they are used in this work in the manner described in the next section, where the methodology employed is presented. Afterwards, a central section describing and discussing the results of the study is included, followed by a final section reporting the main conclusions of the work.

2 METHODOLOGY

Considering the main purpose of this study, the methodology adopted was based on a quantitative analysis of the data available by applying statistical techniques such as descriptive statistics, hypothesis testing (HT) and confidence intervals (CI).

The participants of the study were the students enrolled in the course of Mathematics Concepts I (*Conceitos de Matemática I*) at the University of Aveiro, Portugal, during the academic years 2017-18 until 2019-20. Mathematics Concepts I is part of the first year first semester syllabus of the BED.

The database contains three variables for each student: the academic year, gender, and the average of the grades of the two tests carried out during the course. Only students enrolled in the course for the first time were considered, thus avoiding dependencies between different years, and ensuring the necessary separation between students who were admitted before and after the change in entry requirements. Altogether there were 137 students divided into three groups: 52 students in 2017-18, 42 students in 2018-19, 43 students in 2019-20.

The data was analyzed using the statistical package SPSS, version 22.

The study started with a descriptive statistical analysis. Then, independent samples t-tests were used to compare the average grades obtained by the students in each pair of consecutive academic years. The change in entry requirements occurred in 2018-19 so this year was compared to the previous one (2017-18). The following pair of years (2018-19 and 2019-20) was also analyzed for the purpose of control. To verify the requirements of the t-tests, Kolmogorov-Smirnov Normality tests and Levene's homogeneity of variance tests were performed [14]. The significance level used in all the statistical tests was 5%.

The premise was that the requirement of a mathematics admission exam to the BED had increased the students' preparation and consequently the results in the mathematics courses during graduation. As such, a unilateral independent samples t-test was carried out in order to compare the average grades of the academic year 2017-18 (when there was no entry math exam), and the academic year 2018-19 (when an entry math exam became mandatory). For this t-test the hypotheses in question were:

- H_0: $\mu_1 = \mu_2$
- H_1: $\mu_1 < \mu_2$

Where μ_1 is the average of grades for the year 2017-18 and μ_2 is the average of grades for the year 2018-19.

In the next two academic years, 2018-19 and 2019-20, there was no change in the admission conditions, so it was not expected to observe significant differences in the grades of Mathematical Concepts I. Therefore, it was decided to carry out a bilateral independent samples t-test over the years 2018-19 and 2019-20.

The analysis of the proportion of men in pre-service teachers in Portugal was carried out through the application of the Binomial test to the whole sample. For this test the hypothesis were H_0: $p=p_0$ e H_1: $p< p_0$, where p stands for the male proportion and p_0 stands for 0,5 corresponding to a similar gender proportion. A confidence interval for the male proportion was also determined.

3 RESULTS AND DISCUSSION

The results and their discussion are divided into two subsections: a first one concerning the performance comparison before and after the changes in the Portuguese legislation; and a second one that reports the analysis regarding gender proportion.

3.1 Student Performance in Mathematics

Student performance was analysed through the grades obtained by each student in the course of Mathematics Concepts I. This grade is determined by the mean of the classifications the students obtained in the two written tests carried out during the semester. It should be noticed that grades in Portugal vary from 0 to 20, and grades below 10 lead to failing the course.

A descriptive analysis of the data is summarized in Table 1 and Fig. 1 shows the boxplots of the grades, representing the behaviour of the data in a graphical way.

Table 1. Descriptive analysis of the grades.

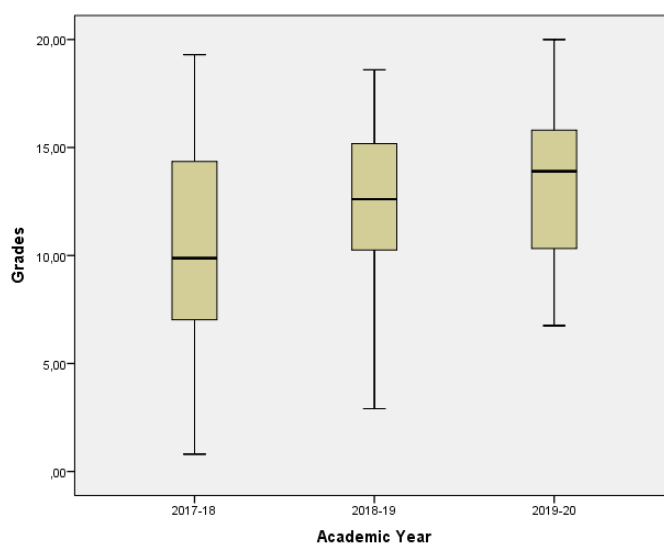| Academic year	2017-18	2018-19	2019-20
Mean	10,42	12,51	13,51
Median	9,88	12,61	13,90
Std. Deviation	4,42	3,63	3,49
95% CI of Mean	[9,19; 11,65]	[11,38; 13,64]	[12,43; 14,58]
Minimum	0,80	2,91	6,75
Maximum	19,30	18,60	20,00

Figure 1. Boxplots of grades for the years studied.

As can been seen in Table 1 the mean and the median of the students' grades, as well as the confidence intervals for the mean of the grades, strongly suggest an increase in the mean grades over the years. Moreover, it can be observed that the standard deviation of the grades shows a decrease throughout the three academic years. The boxplots in Fig.1 reinforce those results.

In order to find out if this increase was statistically significant, independent t-tests to the two pairs of consecutive years were performed. Firstly, however, it was necessary to check the conditions required to apply the t-tests: Normality of the data and homogeneity of the variances.

By applying the Kolmogorov-Smirnov Normality test, with Lilliefors correction, to the three groups of grades it was possible to conclude that the samples may be considered to be withdrawn from populations with Normal distributions (2017-18: K=0,082, df=52, p-value≥0,2; 2018-19: K=0,100, df=42, p-value≥0,2; 2019-20: K=0,093, df=43, p-value≥0,2).

Additionally, Levene's test of homogeneity of variances showed that both pairs of data (2017-18/2018-19 and 2018-19/2019-20) could be considered to have the same population variance (2017-18/2018-19: F=2,286, p-value=0,134; 2018-19/2019-20; F=0,104, p-value=0,748).

Those tests established that the conditions required to do t-tests were met so it was possible to compare the performance of the students in the two pairs of years (2017 18/2018 19 and 2018-19/2019-20) using t-tests.

Since there was a suspicion that the requirement of a mathematics entry exam had increased the preparation of students in this subject, a unilateral test was carried out to compare the grades in 2017-18 with those in 2018-19. For the purpose of control, the grades of the following pair of academic years, 2018-19 and 2019-20, where no suspicion of change existed, were also compared, and so a bilateral t-test was used. Table 2 presents the results of the two t-tests.

Table 2. Results of the t-tests.

Academic years	t statistic	df	p-value	Type of test
2017-18/1018-19	2,463	92	0,008	Unilateral
2018-19/2019-20	1,294	83	0,199	Bilateral

The first test allows us to conclude that there was an increase in the mean grade of 2,09 values, from 2017-18 to 2018-19 and that this increase is statistically significant (p=0,008). The second test allowed us to conclude that the increase of 1.00 in the mean grade observed from 2018-19 to 2019-20 was not considered statistically significant (p=0,199), as expected.

Although not significant, the last increase was considered larger than expected. Therefore, the website of the Ministry of Education [15] was analysed in order to check if there had been an increase in the candidate classifications in these last two years. It was found that the classification of the last student placed had increased about one value (11,40 – 12,58), which may explain the increase observed in the samples studied.

It is important to reinforce that there was a significant increase in grades from 2017-18 to 2018-19 but no significant change in the following years 2018-19 to 2019-20, supporting the hypothesis that the government's measure had a positive effect on ensuring a better mathematics training of pre-service teachers.

3.2 Gender Analysis

A random sample of university candidates is expected to have roughly as many men as women. In Portugal, experience shows that there is a gender tendency in teachers. Most young people who are or want to become teachers are female. In order to analyse if the proportion of males in BED is really lower than expected, a unilateral Binomial test was used, with H_0: p = 0,5 and H_1: p <0,5. The sample consisted of 137 students: 14 men and 123 women. This leads to a point estimate of 10,22% for the proportion of men and since the test provided a p-value smaller than 0,0005, it was possible to reject the null hypothesis in favour of the alternative hypothesis.

Additionally, it was decided to estimate the proportion of men by defining a 95% confidence interval which resulted in the following: $p \in [0,051; 0,153]$. It is thus possible to conclude that, statistically, the percentage of men entering BED is much lower than the percentage of women.

4 CONCLUSIONS

This work aimed at understanding the impact of changes in Portuguese legislation regarding students' math entry requirements. Those changes were analysed by looking at the performance in a mathematics course of students from the pre-service teachers' Basic Education Degree, taught at the University of Aveiro, Portugal.

The main characteristic under study was the evolution of students' grades in that mathematics course, Concepts of Mathematics I, over the last three academic years. This study considered the period between 2017 and 2020, thus including one academic year before changes in legislation occurred and two afterwards. Until 2107-2018 an admission exam in mathematics was not mandatory for BED applicants, but since 2018-2019 that has changed and all BED applicants, in every Portuguese university, must do that exam.

Thus, in this study it was possible to conclude that the change in the entry requirements to the Basic Education Degree, by imposing a mandatory mathematics entry exam as from 2018, caused a statistically significant improvement in the performance of students in mathematics, at the University of Aveiro.

Another of the characteristics studied was the proportion of men among BED students, since over time there has been a predominance of women in this degree. It was concluded that, in fact, the proportion of men was statistically smaller than 50% and the estimated population proportion was between 5,1% and 15,3% (95% of confidence).

The main contribution of this study is the way it exposes how simple statistical techniques can be used to obtain a broader and deeper understanding of how certain changes in legislation can affect the

performance of students throughout their academic path. Also, it is important to note that this type of method can be applied to other situations where it is necessary to evaluate the impact of certain policy changes in the performance of the system under analysis (Higher Education or others), thus helping decision-makers. It is also useful for researchers that wish to understand how this type of analysis can help them in gaining a more in-depth knowledge of the problem they are studying.

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