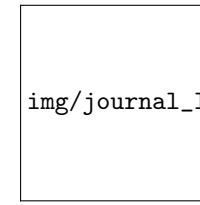

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RESEARCH ARTICLE

Mathematics are Blue and Languages are Pink. A gender-focused, comparative analysis of Catalunya's avaluació de les competències i coneixements bàsics

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Abstract

We have studied two datasets containing the marks obtained by anonymous students of sixth grade of primary school and fourth grade of ESO in the yearly Generalitat essential knowledge and competences exams. These written evaluations measure the students habilities in Mathematics, Science and Languages. We studied the correlations between the median grade of each subject and the sex of the student. We found females consistently outperform males in every language subject, whereas males perform better in Mathematics. No significant difference was found in Science. This trend has already been observed in previous literature with no concise explanation given to this phenomenon. For that reason, new pathways of research are also suggested to shed more light on the dynamics at play.

Keywords: Data analysis; Sex and gender studies; Education; Students of 4 ESO; Students of 6 grade primary school; Avaluació de les competències i coneixements bàsics

1. Background

This study is based on two datasets obtained from the 'Avaluació de les competències i coneixements bàsics', which is a yearly exam proposed by the Generalitat of Catalunya to students in sixth grade of primary school, [2], and fourth grade of ESO, [1]. It measures their capacity to perform in language related subjects and science related subjects. In this study, we have taken into account in particular the subjects of Spanish, Catalan, English, Mathematics and Science. Each grade is calculated as a mean of the results obtained in each individual subject's competences.

Apart from their grades, the identity of the students is completely anonymous. However, some background information is provided; for example, the kind of school they went to or how populated was the municipality they lived in. In this study, we have put our focus into the sex of the student, either male or female, regardless of any other external factors.

The dataset corresponding to sixth grade records data from 2009 onwards, whereas the dataset for the fourth grade starts at 2012. The Science subject records start some time later, in 2016 for sixth grade and 2018 for fourth grade. Additionally, not all subjects have the same amount of entries even if they have started in the same year. We can only guess as to why this happens. For example, the English subject has thousands of entries less than the Spanish subject, even if both subjects are compulsory at high school. This can either be explained because there are less students of third languages or becuase of a loss of data due to an incorrect recording. Some beforehand data manipulation has been needed in order to properly analyze the datasets.

What are we studying?:
We started this study by questioning ourselves whether there would be a difference in each subject's grade if the student were to be a male or a female. It is a well-studied phenomenom, [3], that females usually prefer to develop careers in socially oriented professions whereas males prefer STEM related fields. We would like to know if this tendency is reflected early in childhood measuring its effect in student's school grades.

2. Methods

The Python code used in order to obtain this results can be found at this link.

First we made extracted the information from each column. We clean the duplicated values from each dataset and rename the columns we're interested in for better identifying which subject they are referring to. These datasets are called 'Sexto-sin' and 'Cuarto-sin'. We created two more datasets modified for their better processing later in the code, called 'Sexto-sin-melt' and 'Cuarto-sin-melt'.

Then we make a preeliminar study of the data. For both datasets we compute the marginal probability of each subject per sex of the student using the 'Seaborn' package 'kdeplot'. Afterwards, we plot the medians, the 25 and 75 quantiles along

with the probability distributions per subject per sex using a 'violinplot'.

Finally, we obtain from both datasets the medians and quantiles per year per sex. The following code demonstrates how it was done for the sixth grade of ESO dataset.

```
# Create new datasets with said medians and quantiles

# For the Sixth grade of primary dataset
df1 = Sexto_sin
subjects = ['Catalan','Spanish','English','Mathematics','Science']
# New dataset
medians_df = pd.DataFrame()

for subject in subjects:
    subject_stats = df1.groupby(['ANY',
        'GENERE'])[f'{subject}'].agg(['median', lambda x:
        x.quantile(0.25), lambda x: x.quantile(0.75)]).reset_index()
    subject_stats.columns = ['ANY', 'GENERE', f'{subject}_Median',
        f'{subject}_25th', f'{subject}_75th']
    # Merge with the result DataFrame
    if medians_df.empty:
        medians_df = subject_stats
    else:
        medians_df = pd.merge(medians_df, subject_stats, on=['ANY',
            'GENERE'])
```

3. Results

Marginal probability distributions for each dataset are presented in Figure 3 and 2. We can see the grades are not symmetrically distributed and have a strong skewness towards higher grades, the most different shapes being the fouth of ESO English and Mathematics. This may be due to what exams evaluate, because in the english language evaluation it is required to make a written essay whereas science exams are mostly evaluated by tests.

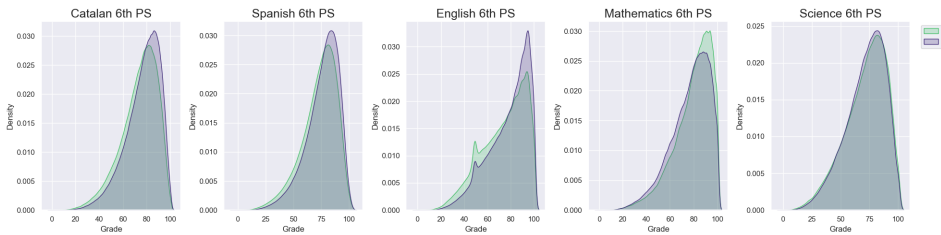

Figure 1. Sixth grade dataset marginal probability density for each subject per sex. Females are denoted by 'D' and males by 'H'. We can see the distributions are not symmetric and peak at different grades depending on the sex of the student. This means a much greater percentage of women will score better than their male colleages in Catalan studies, but the contrary will happen in mathematics.

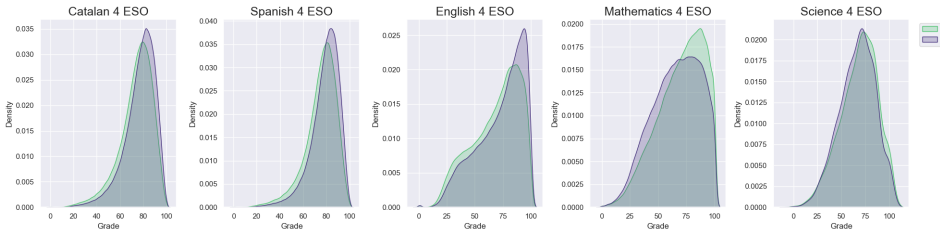

Figure 2. Fourth grade dataset marginal probability density for each subject per sex. Females are denoted by 'D' and males by 'H'. We can see the distributions are not symmetric and peak at different grades depending on the sex of the student. This means a much greater percentage of women will score better than their male colleagues in Catalan studies, but the contrary will happen in mathematics. In particular, female grades are greatly distributed between grades 50 to 75, meaning fewer women will have higher grades. In contrast, males have a gaussian like distribution peaking at grade 90, which denotes males having better grades on average.

In the sixth grade plots we see both genres have roughly the same probability in each subject. It is still noticeable a higher tendency in women, denoted as 'D', to score higher grades in language subjects, whereas males, denoted as 'H', score better results in mathematics. We see the fourth grade plots also reproducing this behaviour.

It should be noted that the plots containing the marginal probability of Science subject have been greatly smoothered. If they had not been smoothered, they would have showed 'peaks' in every round number. Perhaps this could be due to how the exam were prepared or to how were they marked.

In order to conduct a further study we compute the medians, 25 and 75 quantiles and compare the results between the sexes. We do not compute the mean because our data is asymmetric and therefore its value would not be representative.

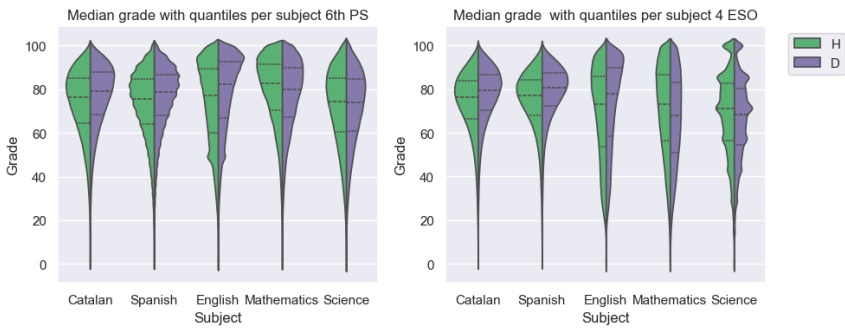

Figure 3. Graph showing the probability density function and the medians (thick dotted line), 25 and 75 quantiles (small dotted lines) for each subject per sex. Females are denoted by 'D' and males by 'H'. We can see in language related subjects, the median of females is higher than the median of males; happening the other way around in mathematics and science. However, in 6th grade we observe similary in the results between males and females.

From Figure 3 we can conclude there are significant differences in the median

grade between the sexes. These differences seem to grow bigger in fourth of ESO students. The quantiles are proof of the spreadness of the data, which indicates the randomness of the population.

The shape of the marginal distribution for Spanish of sixth of primary school and the shape for Science in fourth of ESO are spiky because the probability function has not been smoothered. It should be argued whether these exams have been recorded with enough quality so as to give us unbiased results.

Finally, we study the medians and quantiles over time per subject per sex. The following tables, Figure 4 and Figure 5, show the numerical results for the median and Figure 6 presents them graphically.

Students of 6 PS		Year												
Subject	**Sex**	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2021*	*2022*
Catalan	H	78,31	76,4	77,3	81,3	72	76,9	76,1	75,5	77,3	73,7	76,2	78,1	73,1
	D	80,72	76,8	81,4	84,6	75,3	79,6	78,8	78,2	80,9	77,1	79,8	81,8	77,6
Spanish	H	75,61	71,4	73,2	78,1	74,6	76,9	76,7	74,5	77,3	77,9	75,9	75	75,3
	D	79,27	75,2	77,7	80,6	76,9	79,2	79,8	77,3	77,3	81,2	79,8	77,5	78,2
English	H		71,6	82,4	74,1	73,4	77	71,3	74,5	83,3	79,2	81,3	74,6	78,8
	D		79,1	83,9	78,4	79,6	82,7	79,2	78,9	86,3	83,8	86,7	81,3	84,2
Mathematics	H	83,13	83,1	85,5	87,2	81,9	86	82,4	83,1	83,3	84,4	80,5	81,1	74,8
	D	79,52	79,5	82,3	82,8	78,9	83,7	80,6	80,1	79,55	81,5	78,7	79,3	73,7
Science	H										73,8	70,2	78,6	76,1
	D										72,5	70,2	79,2	75,3

Figure 4. Median grade per sex per year. Females are denoted by 'D' and males by 'H'. We can see there are gaps in the yearly recordings.

Students 4 ESO		Year										
Subject	**Sex**	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Catalan	H	73,8	78,3	78,1	73,5	78	74,4	76,8	79,2	74,2	76,6	74,3
	D	76,3	79,9	81,2	75,5	81,2	79,2	81,7	80,3	78,1	81,4	78,15
Spanish	H	75,4	77,4	76,6	76,7	76,8	77,9	77	79	77,6	78	75,45
	D	77,8	79	79,5	79,3	80,5	81,6	81,7	81,8	82,4	82,7	80,2
English	H	69,2	72,1	68,8	70,5	73,8	76,8	77	76,8	1	72,6	68,4
	D	73,6	77,3	73,7	75,8	78	80,6	80,6	81,2	1	78,8	76,4
Mathematics	H	72,8	76	75,4	73,3	72,1	75,7	73,5	71,7	76,6	71,6	66,11
	D	64,3	67,9	69	69	66,8	71	65,6	68,3	80,4	64,1	57,78
Science	H					70,4	69,2	68,8	68,4	85,7	66,1	69,07
	D					68,5	66,3	67,7	66,5	85,7	64,2	65

Figure 5. Median grade per sex per year. Females are denoted by 'D' and males by 'H'. We can see there are fewer gaps in the yearly recordings, compared to the sixth grade dataset.

The tendency of males to score better median grades than their female colleages in mathematics is mantained, being the other way round with language related subjects. In languages,we observe the difference in English is greater than Spanish or Catalan. In scientific subjects, we can see there is only a slight difference over time in Science, whereas Mathematics, specially in fourth of ESO, have the most significance in the median grade between the sexes.

Figure 6. Plot of the median grade per subject per sex. The coloured zones are the 25 and 75 percentiles. Females are denoted by 'D' and males by 'H'. We can see the difference in the median grade between sexes is mantained throughout the years. This difference is specially significant in language related subjects and mathematics.

4. Conclusions / Discussion

In conclusion, our examination focused on the median grades for each subject, considering both overall performance and year-wise comparisons between male and female students. Our findings reveal that females generally achieve higher median grades than males in language-related subjects; specifically, Spanish, Catalan, and English, while males tend to outperform in Mathematics. These trends were observed consistently across both the comprehensive and temporal aspects of our study. In addition, both genders exhibit relatively similar performance in Science, although it's worth noting that the comparatively smaller amount of data could potentially weaken this result.

Furthermore, we observed that the disparity in median grades is more pronounced among fourth-year ESO students compared to sixth-grade primary school students. Notably, English and Mathematics showcase the most significant differences between genders.

This pattern has been previously documented in other studies involving adolescents in Andalusia [4]. In this particular study, beyond academic grades, each student underwent evaluation regarding their self-perception in various areas, including social and self-confidence aspects. A performance disparity between genders was identified, with females exhibiting better performance in Spanish. While no significant difference was found in Mathematics grades, it was discovered that, among equally proficient students, males tended to have more confidence in their abilities than females.

Consequently, the ease with which males excel in mathematics may influence their inclination toward pursuing STEM-related careers. Similarly, women's superior performance in languages may steer them toward careers in social and language-related fields, such as education or linguistics. Nevertheless, these observations do not fully address our inquiry. To determine whether these academic outcomes influence subsequent career choices, further longitudinal research is essential. Additionally, a

broader range of subjects, including Biology or Physical Education, should be examined to gain a comprehensive understanding of grade and gender differences.

Notes

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