



# Academic Performance under Multidimensional Influences: An Empirical Analysis of Mathematics Achievement among Portuguese School Students

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**Abstract.** Education constitutes a cornerstone of societal development, with student academic success holding significant weight for both government policy and societal advancement. Particularly in the realm of mathematics, student performance serves as a barometer for educational achievement and cognitive capacity. This paper delves into a comprehensive analysis of the multifaceted factors influencing mathematical prowess among students, and focuses on analyzing the factors that affect student performance, including external factors such as family background and societal milieu, as well as internal factors such as students' attitudes toward learning and their methodological approaches to the subject. Through a rigorous investigation, the study endeavors to reveal how these factors independently and collectively impact students' mathematical performance for prediction, and culminates in bespoke targeted improvement strategies based on the findings. This research promises to furnish education stakeholders, including policymakers and pedagogues, with actionable insights, underpinning effective interventions for elevating students' mathematical proficiency.

**Keywords:** Education, Data Analysis, Regression Analysis.

## 1 Introduction

Student performance is an important indicator of students' learning outcomes at a certain stage, and the influencing factors of student performance can be explored from both external and internal perspectives.

Family background is one of the important factors that affect student performance. Family background includes parents' educational level, economic status, family atmosphere, etc. Family background has a significant impact on student performance. Students from well-off families usually have access to better educational resources and a better learning environment, thus having a greater chance of achieving good grades. On the other hand, students from less privileged families may face various limitations and challenges, affecting the improvement of their academic performance. Family environment has a certain impact on elementary school students' academic performance. Re

search has found that besides living area and family income having no impact on students' academic performance, differences between high-scoring and low-scoring groups in terms of family type, parents' educational level, parents' occupation, parents' relationship, and primary caregivers are statistically significant ( $P < 0.05$ ). Among them, children in the high-scoring group are mainly from nuclear families, with parents having a high school education or above, working as workers or officials, having harmonious parent relationships, and being primarily cared for by their parents. On the other hand, in the low-scoring group, children are mostly from single-parent families, with poor parent relationships, parents having an educational level below junior high school and working as farmers or urban residents. Additionally, most children are mainly cared for by their grandparents or other relatives.[1] Is the family background beneficial to students' academic development? Research shows that when students' grades do not reach the school's division threshold score, students from advantaged families are more likely to enter high-achieving classes, while when grades reach the division threshold score, the probability of students from disadvantaged families entering high-achieving classes significantly exceeds that of advantaged families by 34%, with advantaged students only exceeding by 19%. This means that the ability-based streaming system provides academically excellent students from disadvantaged families with the opportunity for educational mobility, but overall, it effectively maintains inequality. From a procedural fairness perspective, disadvantaged students entering high-achieving classes and experiencing grade improvements mainly benefit from having higher quality and more advantaged classmates, as well as a reduction in the risk of campus bullying. In other words, the ability-based streaming system builds a "glass wall" that isolates unfavorable conditions but adheres to the unfair principle of "separate but equal." From a fairness of outcomes perspective, disadvantaged students entering high-achieving classes significantly improve their grades by 0.38 standard deviations, achieving the efficiency goal of fair outcomes, but there are still concerns about "class solidification." [2]

Furthermore, learning attitude is an important factor that influences student performance. Students' attitude towards learning determines their level of importance placed on learning and their initiative in learning. A positive and proactive learning attitude can inspire students' interest and motivation in learning, thereby enhancing learning outcomes. Research results have shown that undergraduate students and professional master's students in medical statistics have a positive correlation between their learning attitude and exam scores.[3] Not only undergrads and grad students, but also when it comes to lower grade levels like high school, junior high, and vocational schools. The attitude towards learning still plays a crucial role in academic performance.[4][5][6]

In addition, educational resources and educational environment are also important factors affecting student achievement. Educational resources include teachers, teaching facilities and teaching resources, while educational environment includes educational atmosphere and teaching atmosphere. In China, after-school training institutions also play an extremely important role in education. Take New Oriental and TAL, two of China's biggest training institutions. From the perspective of the number of students and institutions, from December 2020 to February 2021, the total number of students enrolled in Hao Future (up to 6.691 million, up 44% compared with 4.646 million in

the same period last year), and the number of students enrolled in New Oriental reached 2.2968 million, up 43% compared with the same period last year. New Oriental prefers offline expansion. As of the end of February 2021, the number of offline stores of New Oriental reached 1,625, and the number of offline stores of TAL was 1,098. In addition, TAL spent \$661 million on marketing from December 2020 to February 2021, while New Oriental spent \$156 million on marketing, according to TAL's latest financial report. In terms of overhead, TAL's overhead was \$349 million, while New Oriental's overhead was \$393 million.[7] Therefore, in China, extracurricular training institutions constitute a massive industry. A huge industry inevitably brings intense competition, so for these institutions, they also strive to improve educational standards; otherwise, they risk being eliminated. In such fierce competition, it also drives improvements in the educational atmosphere, educational standards, enriching educational resources. Furthermore, in this extensive scenario, it's evident that both parents and students are willing to invest a significant amount of money in extracurricular tutoring to enhance academic performance. This prompts an investigation into the efficacy of such additional instruction. To wit: does this extracurricular tutoring actually work? Can these excellent educational resources and environment provide better learning conditions and opportunities, beneficial for improving student performance?

Furthermore, students' personal qualities and abilities are also crucial factors influencing academic performance. Students' self-control, discipline, communication skills all affect their learning outcomes. For instance, alcohol intake, which actually poses a significant issue for academic performance. Studies both domestically and abroad indicate that alcohol abuse among college students is a serious problem that cannot be ignored, severely damaging students' physical and mental health, academic performance, and social functioning.[8][9][10][11] Even at the national level, youth alcohol control is highly regarded in many countries. For example, in the United States, federal law states that individuals under 21 cannot purchase or possess alcoholic beverages. Currently, most states in the US support this law. Violating this law can result in fines of up to \$1000; in severe cases, community service such as cleaning parks or participating in public service projects may be required. According to Canadian law, children and adolescents under 18 are prohibited from drinking. Even for international students under 19, even if they have reached the legal drinking age in their home country, they cannot drink in Canada. Those who violate Canadian regulations may face a range of penalties, including fines, paying fines, community service, license revocation, and even criminal prosecution for serious offenses. Students must remember the laws and regulations to avoid such violations. Additionally, controlling smoking and possessing good personal qualities and abilities can help students better adapt to the learning environment, grasp knowledge effectively, and achieve better grades.

Lastly, social environment and societal pressure are also factors influencing student performance. The societal environment and pressure can impact students' attitudes towards learning and their academic outcomes. The pressure for further education is immense; The national average admission rate for 985 universities (a collection of top schools in China) in China is about 1.62%. Admission rates vary across provinces. Henan has the lowest rate at 0.84%. Tianjin, Beijing, and Shanghai have higher rates at 5.81%, 4.3%, and 5.3% respectively. Overall, the admission rate for 985 universities is

low. In 2022, there were around 10.76 million college graduates in China. The youth unemployment rate is 20.8% for individuals aged 16 to 24. Many graduates face unemployment, relying on their parents for income.

Therefore, in this competitive social environment, students may encounter various pressures from Huangexams, academics, etc., all of which can impact their academic performance. In-depth research into predicting student performance and analyzing influencing factors can help improve educational quality, promote student development, drive educational reform, and play a crucial role in achieving educational modernization and comprehensive.

## 2 DATA

### 2.1 Data Source

The dataset comes from the UCL Machine Learning Repository, provided by Paulo Cortez from the University of Minho in Guimaraes, Portugal. It compiles the academic performance of students from two Portuguese high schools, including student grades, demographics, and school-related features collected through school reports and survey forms. Two datasets are provided, one for Mathematics (mat) and the other for Portuguese language (por) performance. In the study by Cortez and Silva, 2008, these datasets were used for binary/five-level classification and regression tasks. It's important to note that the target attribute G3 (final grade) has a strong correlation with attributes G2 (second semester grade) and G1 (first semester grade). This is because G3 represents the final grade (3rd stage), while G1 and G2 correspond to the 1st and 2nd stages respectively. Predicting G3 without G2 and G1 can be more challenging, but such predictions are more practical.[12]

### 2.2 List of Variables

All the influencing factors are shown in Table 1 below:

**Table 1.** Composition of data information

Variants	Explanation
age	student's age
absences	number of school absences (from 0 to 93)
school	student's school
sex	student's sex (female or male)
address	student's home address type (urban or rural)
famsize	family size
Pstatus	parent's cohabitation status (living together or not)
Medu	mother's education (range 0-4)
Fedu	father's education (range 0-4)
Mjob	mother's job ('teacher', 'health' care related, civil 'services' (e.g., administrative or police), 'at home' or 'other')

Fjob	father's job ('teacher', 'health' care related, civil 'services' (e.g., administrative or police), 'at home' or 'other')
reason	reason to choose this school (close to 'home', school 'reputation', 'course' preference or 'other')
guardian	student's guardian ('mother', 'father' or 'other')
traveltime	home to school travel time
studytime	weekly study time
failures	number of past class failures
schoolsup	extra educational support (yes or no)
famsup	family educational support (yes or no)
activities	extra-curricular activities (yes or no)
paid	extra paid classes within the course subject (Math or Portuguese)
nursery	attended nursery school (yes or no)
higher	wants to take higher education (yes or no)
internet	Internet access at home (yes or no)
romantic	with a romantic relationship (yes or no)
famrel	quality of family relationships (from 1 - very bad to 5 - excellent)
freetime	free time after school (from 1 - very bad to 5 - excellent)
goout	going out with friends (from 1 - very bad to 5 - excellent)
Dalc	workday alcohol consumption (from 1 - very bad to 5 - excellent)
Walc	weekend alcohol consumption (from 1 - very bad to 5 - excellent)
health	current health status (from 1 - very bad to 5 - excellent)

Factors can be divided the following complex variables into four parts: personal situation, family situation, environmental factors, and social relationships. Personal situation includes: age, number of absences, gender, reasons for school choice, commuting time, study time, number of failed subjects, participation in paid educational activities, attendance at nurseries, expectations of receiving higher education, alcohol consumption, and health status. Family situation includes: family address, family size, whether parents live together, parents' education and work, educational support provided by the family, and parental relationships. Environmental factors include: school, guardians, and educational support provided by the school. Social relationships include: frequency of exercise, internet usage, romantic relationships, leisure time, and frequency of going out with friends.

### 3 DATA ANALYSIS

#### 3.1 Independent Sample T-test was Used for Analysis

Next, I will predict and analyze the impact of various factors such as students' gender, home address, and parents' cohabitation status on students' final grades using an independent samples t-test.

### 3.1.1 By gender: Boys Show a Stronger Aptitude for Mathematics.

Through the independent samples t-test, the p-value is 0.040\*\*, indicating that gender, whether male or female, has a significant impact on the final grade G3. Additionally, the average scores of students who attended extra paid courses are shown in the following graph(Figure 1), and the average scores of male and female students are displayed in the following graph.

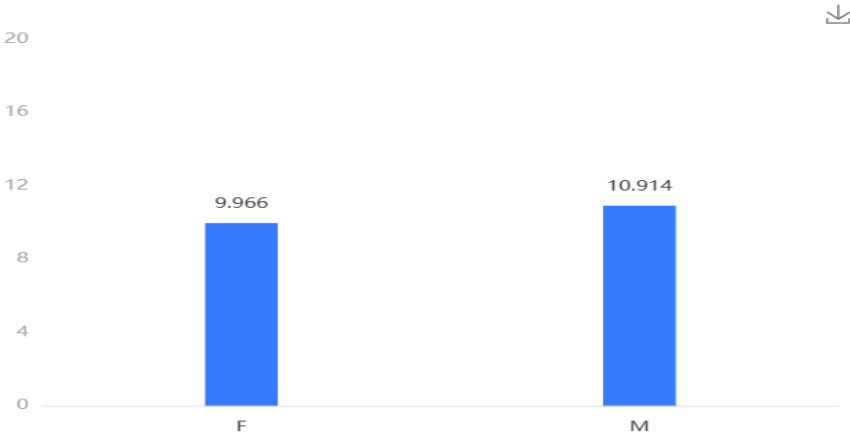
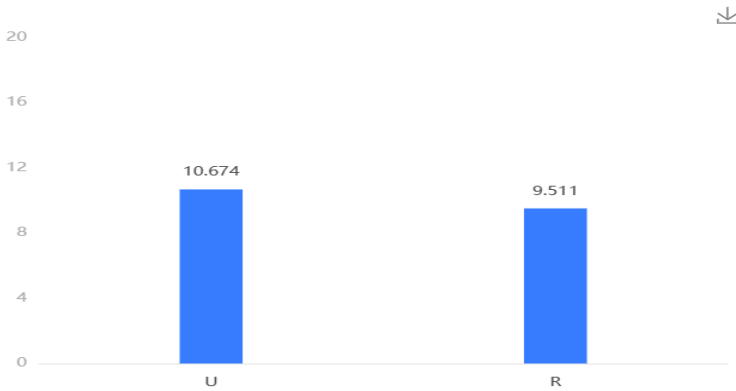


Fig. 1. Comparison of Average Grades Between Male and Female Students

Comparing the left side of the graph, which shows the average score of female students, with the right side, which shows the average score of male students, seeing that the average score of male students is 0.948 points higher than that of female students. So, it is obviously that the average grades of male high school students are significantly higher than those of female students, which could be due to various reasons. Previous psychological studies have suggested that boys may be more proactive and confident in their studies, making it easier for them to stay focused and engaged in learning. Additionally, in some countries, males are expected to excel academically and have more achievements in the future. This could lead to greater academic pressure on boys, motivating them to study harder. Furthermore, since this data includes math scores, some studies indicate that boys may have a stronger aptitude for mathematics, which could result in better performance in these subjects.

### 3.1.2 Family Address: Urban Area Show a better Academic Performances than Rural Area.

Through independent samples t-test, with a p-value of 0.036\*\*, it is evident that living in urban or suburban areas has a significant impact on the final grade G3. The relationship between final grade G3 and the average grades of students living in urban or suburban areas is shown in the Figure 2.

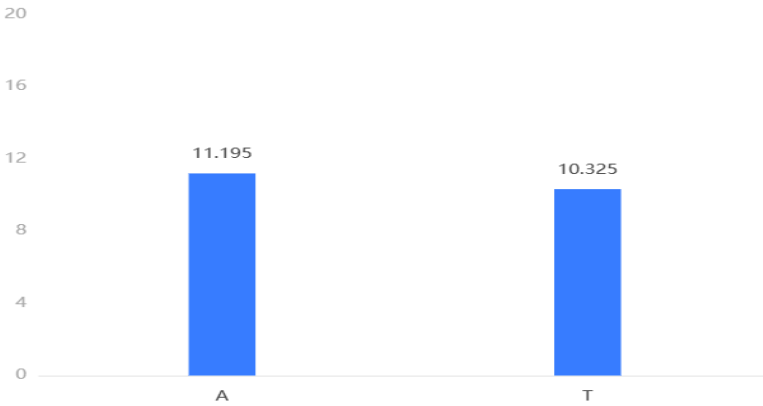


**Fig. 2.** Comparison of Average Grades Between Students Living in Urban or Suburban Areas

Students living in urban areas have an average score of 10.674, while students living in rural areas have an average score of only 9.511. Noticing that students living in urban areas have significantly higher average grades than students living in rural areas, which may be because urban areas typically have richer educational resources, including better school facilities, more educational opportunities, and higher-quality educators. These resources can provide a better learning environment and more opportunities for students, benefiting their learning and development. Secondly, families in urban areas generally have higher levels of education and place a greater emphasis on education. These families may provide children with more learning support and encouragement, motivating them to study harder. The different social environments in urban and suburban areas are also major factors affecting students' average grades. The social environment in urban areas is more open and diverse, allowing students to access a broader range of knowledge and information, sparking their interest and potential for learning. Finally, the learning atmosphere in urban areas may be more intense, with competition among students and a strong learning environment motivating students to study harder and improve their academic performance.

### **3.1.3 Cohabiting of Parents: A Warm Family Atmosphere Provides Limited Benefits.**

Many families strive to cohabit as much as possible for their children's development, aiming to provide a happy family environment for their children. However, through independent samples t-test, with a p-value of 0.250, it is evident that the parents' cohabitation status does not have a significant impact on the final grade G3. Whether parents separate due to work reasons or divorce, the most important thing is to provide children with sufficient support and love in life, enabling children to achieve good academic results. Some parents may cohabit but neglect their children's education and care, leading to unsatisfactory academic performance. Therefore, parents' actions are more important than whether they live together.



**Fig. 3.** Comparison of Average Grades Between Students Living in A Warm Family Atmosphere or Not

The comparison results in Figure 3 and the T-test results show that whether parents live together or apart does not have a significant impact on students' academic performance.

### 3.2 Regression Model

After analyzing the grades using a linear regression model, the regression model is established:

**Table 2.** Results of Regression Analysis

	Regression Coefficient	P-value	R <sup>2</sup>	Adjusted R <sup>2</sup>
constant	13.487***	0.001	0.243	0.18
age	-0.355*	0.091		
absences	0.05*	0.083		
school	0.672	0.392		
sex	1.119**	0.026		
address	-0.574	0.324		
famsize	0.703	0.149		
Pstatus	-0.498	0.489		
Medu	0.551*	0.055		
Fedu	0.018	0.944		
Mjob	-0.17	0.401		
Fjob	0.031	0.902		
reason	0.195	0.286		
guardian	0.22	0.556		
traveltime	-0.276	0.417		



studytime	0.504*	0.078		
failures	-1.599***	0		
schoolsup	1.202*	0.072		
famsup	-0.793*	0.099		
activities	-0.338	0.447		
paid	0.303	0.522		
nursery	0.158	0.775		
higher	-1.253	0.24		
internet	0.481	0.434		
romantic	-1.054**	0.025		
famrel	0.197	0.421		
freetime	0.306	0.193		
goout	-0.57**	0.012		
Dalc	-0.218	0.502		
Walc	0.191	0.433		
health	-0.118	0.457		
Dependent Variable: G3				

Note: \*\*\*, \*\*, \* representing significance levels of 1%, 5%, and 10%, respectively.

From Table 2, it can be noticed that factors such as gender, number of failed subjects, romantic relationships, and frequency of going out with friends significantly affect students' final grades, as follows:

Gender has a significant impact on final grades, with males scoring 1.119 points higher on average than females. The number of failed subjects also significantly affects grades, with each additional failure resulting in a 1.599-point decrease in the average grade. Furthermore, being in a romantic relationship has a notable impact on grades, with students in relationships scoring 1.054 points lower on average than those without. Additionally, the frequency of socializing with friends significantly influences grades, with each additional outing correlating with a 0.57-point decrease in the average grade. This also notice some conclusions that may not align with common beliefs, such as the impact of family educational support. People often assume that students with financial support for education at home would achieve higher grades, but the reality is different. This discrepancy may be because in some countries, only students with poor grades attend extra classes for tutoring, leading to the observed phenomenon. Additionally, extra classes might contribute to an excessive study burden, lack of rest time, study anxiety, and mismatched learning styles. To improve children's learning outcomes and grades, parents and teachers need to effectively manage children's study time, ensure they have enough rest and relaxation time, help them alleviate study pressure and anxiety, and choose extracurricular classes that suit their learning styles and habits.

The amount of alcohol consumption does not significantly impact academic performance, whether on weekdays or weekends. It's important to note the correlation between studying and drinking behavior; drinking habits may not directly cause variations in academic performance but could be influenced by other factors such as personal qualities and social circles. However, the indirect effects of alcohol consumption on academic performance should not be overlooked. Alcohol consumption might affect a

child's physical and mental health, subsequently influencing academic performance, but these effects may take longer to manifest, and short-term data may not accurately reflect this impact.

The size of the family does not significantly affect students' grades because family size does not equate to educational resources within the family. Family size does not necessarily indicate the level of educational resources and support within a family. Even in larger families, if there are sufficient educational resources and support, a child's academic performance may not be greatly affected. Family atmosphere and educational philosophies are decisive factors; family size does not necessarily determine the educational atmosphere and philosophies within a family. Even in larger families, if education is valued and learning is emphasized, a child's academic performance may be positively influenced. Additionally, we should consider the influence among siblings; in larger families, parental attention and additional educational support for each child may be limited, potentially impacting their academic performance negatively. However, it could also increase competition and interaction among siblings, which could promote a child's learning and growth, thereby positively impacting academic performance.

## 4 Conclusion

In the study of predicting and analyzing factors influencing students' academic performance, I delved into the prediction methods and influencing factors of students' grades, finding that students' grades are influenced by various factors. By analyzing aspects such as students' personal factors, family factors, school factors, and social environmental factors, can having a more comprehensive understanding of the formation process of students' grades, providing more effective guidance and support for predicting and improving students' grades.

Firstly, found that predicting students' grades can be achieved through various methods, including regression models based on students' historical data. These methods can help schools or educational institutions better understand students' learning situations, identify problems in a timely manner, and take effective measures for intervention to improve the accuracy and reliability of predicting students' grades.

Secondly, analyzed the influencing factors of students' grades, including students' personal factors such as learning attitude, learning motivation, confidence, family factors such as family educational background, family support, and encouragement, school factors such as teaching quality, teaching resources, and social environmental factors such as urban-rural differences, socioeconomic status, etc. These factors interact with each other, collectively influencing students' performance and development.

Lastly, it is important to emphasize that improving students' grades is not only the responsibility of schools and teachers but also requires the joint efforts of families and society. Families should provide children with more support and care, creating a good learning environment; society should offer more educational resources and opportunities, reduce urban-rural disparities, and promote educational equity. Only through the

collective efforts of all parties can achieve the improvement and comprehensive development of students' grades.

To sum up, predicting students' grades and analyzing influencing factors is a complex and important subject that requires considering various factors comprehensively and conducting research and practices through various methods.

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