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Communication

First Grade GPA as a Predictor of Later Academic Performance in High School

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Abstract: The GPA is a universally recognised and utilised metric of academic performance that is considered to also measure a student's potential for academic performance in the future. In this short communication we examine to what extent the GPA of the first grade of high school predicts performance in the later grades of high school, either generally (as classified in an excellent student, strong student, weak student, or very weak student) or more accurately (as indicated by the exact GPA in the next grade). We also put to the test the widely held notion that it might be best if core courses such as language and mathematics contributed more to the calculation of the GPA compared to secondary courses such as physical education or music. Our findings confirm the predictive properties of the GPA but strongly rebut the notion that a weighted GPA might achieve a better reflection of students' potential. The study is based on the academic records of every student in Greece that progressed from the first to third grade of high school in the 2016–2019 period. This dataset contains records of more than 85,000 students, making it one of the most extensive studies ever conducted on the topic of the properties of the GPA.

Keywords: GPA; high school; academic potential; predictive property; weighted GPA

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1. Introduction

The concept of Grade Point Average (GPA) stems from multiple theoretical bases on the measurement and evaluation of student achievement and academic success [1,2]. The GPA attempts to quantify a student's overall performance in different courses with a single measurement. As a common statistic, it is objective and applied equally and uniformly to all students and it is also a measurable statistic that allows for simple comparison with other students and represents prior academic success, which is considered to indicate a student's proficiency [3].

The advantages of using GPA include its simplicity (it is just one number), objectivity (it is based on numerical values, instead of qualitative estimations), and recognisability (it is used, known, and understood throughout the world). It is also considered to be an accurate representation of a student's performance and potential. This is supported by a number of studies that identify a strong link between first-year GPA and end of studies performance [4,5] or end of studies GPA with professional success [6] or success in graduate studies [7–11], although studies also exist that question the strength of such links [12–14].

In the past, grades were only used to evaluate a course or institution [15]. Nowadays, GPA can be used pre-conditionally to gain or lose educational opportunities for students [16]. For this reason, GPA extrinsically motivates students to study [17]. Extrinsic motivation makes students focus on the glowing letter they receive at the end of the year instead of learning and improving in the classroom. This condition has some negative effects. Grades become more important, changing classroom learning and student behavior,

who seek a symbolic measure instead of actual learning [17]. It also has the consequence of affecting student behavior, increasing anxiety, and harming institutions that rely on unfair measures [17]. At the calculation level, GPA has been found to have some validity and reliability issues [3,18–21].

But what about earlier than that? Research efforts focusing on previous levels of education treat GPA as a given research input rather than a focus of the study. For example, studies focusing on high school suggest that a high GPA at the end of high school can be linked to better performance in college/university [22–26]. And in numerous studies focusing on either elementary or high school, researchers examine how GPA is affected by various factors such as social background [27], learning styles [28], family situation [29,30], health [31], etc.

The factors that affect GPA and can be used as explanatory variables are broken down into two general categories: internal and external factors, according to the big meta-analysis of 2138 papers from Karadag [32].

- Internal factors include learning motivation [33], learning style [34], students' attitudes [35], self-efficacy [36], self-concept [37], self regulation [38], self-esteem [39], and goal orientation [40].
- External factors include educational leadership [41], school culture [42], school climate [43], teachers' expectations [44], parent involvement [45], and socioeconomic status, as proposed by Coleman [46].

The common trend in academic achievement research is to predict academic achievement through numerical prediction, regression, or categorisation and decision trees. Student marks are important characteristics for these analyses. A widely used variable for analysis is the GPA.

What is missing is research on whether the GPA in elementary or early years of high school is a good description of a student's potential and a good predictor of the student's future academic success. In this short communication, we focus on high school and examine the GPA metric from three different perspectives, which form the research questions for our study:

- (RQ1) Exactly how good is the GPA in the first grade of high school as a predictor of the rough future academic performance?
- (RQ2) Exactly how accurate is the GPA in the first grade of high school as a predictor of GPA values in later high school grades?
- (RQ3) Is the current way of calculating the GPA in high school the best, or would an approach that gives more weight to the core courses provide a better reflection of a student's true potential?

In order to answer these questions, we analyse the full academic records of every student attending high school in Greece over a period of three years, from 2016 until 2019. In order to facilitate the reader, we examine each question separately. Specifically, the rest of the article is organised as follows. In Section 2, we present the dataset upon which we have based our study. Following that, we start presenting our study in Section 3, where we examine how the GPA in the first grade of high school is related to the academic performance in the second and third grades. Section 4 follows with an examination of how the GPA changes as students progress from one grade to the next. Finally, Section 5, compares the predictive ability of the conventional GPA with that of adjusted GPA metrics that also consider the relative importance of the courses. In closing, Section 6 summarises our findings and identifies areas for future research.

2. Dataset

The Educational Management Information System (EMIS) of the Greek Ministry of Education records information regarding all students attending any of the fourteen levels of primary and secondary education, including those who attend private schools. School

principals across the country are responsible for entering the data. Information recorded in EMIS includes the following:

- Demographic characteristics of the students and their families, such as age, gender, profession of parents, nationality, religious affiliation, etc.
- Records of the students' academic performance, such as grades per subject, absences in class, and notes on behaviour.
- Information regarding the teaching staff, such as their contractual status, their contact information, the classes they teach, the number of hours they teach each week, the qualifications they possess, their historical teaching and employment records, etc.
- Data regarding the schools, such as their address, the contact person, facilities and resources available, requests they have submitted for the recruitment of additional teachers, etc.

For this study, we have been provided with a segment of this dataset. Specifically, we have been provided with full academic records for all students attending the first, second, and third grades of high school during three consecutive academic years, namely 2016–2017, 2017–2018, and 2018–2019.

There is a standardised curriculum throughout the country, which all schools, whether public or private, are required by law to follow. Similarly, the standardised curriculum is complemented by standardised guidelines on how to assess and grade student performance. In Greece, different schools are not independent institutions, as is the case with universities, which are freer to determine their own teaching priorities. Schools are branches of the same single institution (the Ministry of Education), have no self-government, and operate in a uniform manner in all respects. This allowed direct comparability of grades between different types of schools.

The data provided by the Greek Ministry of Education covered the total number of public schools of general education (not special education) in the country. The dataset is anonymised, i.e., it is not possible to identify any specific student or school. It contains pseudo-identifiers (the same unique ID is associated with all the records that are related to the same student), which allows us to track students' progress from one grade to the next.

There are in total 296,733 records in the dataset, each one corresponding to a student's records for an academic year, as outlined earlier. The total number of primary and secondary (junior high) schools is 5056 and 1677, respectively. A brief presentation of the dataset and a first look at some conclusions that can be drawn from analysing it have been included in our earlier work [47]; in that work, the focus was on the way demographic data correlate to academic performance, while here we focus on the predictive properties of the GPA metric.

It is of course most common for a student that starts the first grade of high school in a given year to finish the third grade of high school three years later. But not every single student in the country progresses through the academic grades at the same pace. Some are forced to repeat a year due to illness, poor performance, or other adverse situations. Others move abroad or drop out of school entirely, disappearing from the school system records. And some others follow the opposite direction, for example, coming from abroad and joining the Greek educational system at an intermediate grade without the system having any prior records for them. As a result, not all records are part of a typical three year progression.

As we need to track students over a three-year progression through the grades of high school in this study, we use the pseudo-identifiers to associate the records of the three years that correspond to the same students moving through the three grades and discard records that are not part of the typical progression. As shown in Table 1, this process leaves us with 85,344 complete records.

Of course, the three school grades considered in our study do not all include exactly the same courses in their curricula; in Table 2, we summarise the courses taught in each grade. Firstly, we observe that there are differences in the core courses offered. For example, the third grade has "Social and Political Education" that is not offered in grades 1 and 2, and similarly, the first grade has "Home Economics", which is not offered in later grades.

Moreover, there are courses that are not offered to all students. Examples include "Religious Education", for which some students request and receive an exemption, and languages other than English, because each student can only select one additional foreign language. To that we should add that in numerous schools, none of the additional languages are offered due to the lack of competent teachers.

Table 1. Consolidation of records.

Grade	Records in the Original Dataset	Retained Records That Span the 3-Year Period
1st grade	96,359	
2nd grade	99,431	85,344
3rd grade	100,943	

Table 2. Courses in the curriculum. ✓ indicates courses offered, X indicates courses not offered, and (✓) indicates courses that are offered only in some schools or only for some students.

Course	1st Grade	2nd Grade	3rd Grade
Greek Literature	✓	✓	✓
Greek Language	✓	✓	✓
Ancient Greek Language	✓	✓	✓
Religious Education	(✓)	(✓)	(✓)
History	✓	✓	✓
Mathematics	✓	✓	✓
Home Economics	✓	X	X
Computer Science	✓	✓	✓
Technology	✓	✓	✓
Physics	✓	✓	✓
Biology	✓	✓	✓
Geography	✓	✓	X
Chemistry	X	✓	✓
Social and Political Education	X	X	✓
Music	✓	✓	✓
Physical Education	✓	✓	✓
Skills Workshops	✓	✓	✓
English Language	✓	✓	✓
French Language	(✓)	(✓)	(✓)
German Language	(✓)	(✓)	(✓)
Italian Language	(✓)	(✓)	(✓)

As a result, academic performance records are not easy to compare from grade to grade, or even from student to student within the same grade. In order to overcome this, the students' GPA is calculated and is used as the core parameter based on which we assess academic performance and track progress from grade to grade; in some records, it is the average of the student's performance across 19 courses, while in others, it considers as few as 13 courses, the average being 17.7 courses per student and school grade.

Having completed the pre-processing of the data (linking records of different grades, cleaning the records that are not part of a typical three-grade progression, and calculating the GPA values), we are left with 85,344 triplets of GPAs, corresponding to individual students' performances across the three grades of high school. This is the data upon which our study is based.

3. RQ1—Prediction of Future Academic Performance

In earlier work [47], we found that across both elementary and high school, pupil and student performances can be classified in four groups of different potential, based on

course scores and using a method such as k-means. We also found that students tend to remain in the same performance group across many years of studies.

In order to assess how well the GPA reflects the students' current performance and future potential, we start by using k-means in order to cluster the students of each grade into four groups. The groups correspond to the following:

- Group A with the highest centroid value: excellent academic performance;
- Group B with the second highest centroid value: strong academic performance;
- Group C with the third highest centroid value: weak academic performance;
- Group D with the lowest centroid value: very weak academic performance.

In k-means, the centroid is an imaginary ideal member of a cluster whose parameters are the average of the corresponding parameters of all the actual members of the cluster. In our case, the centroid value is the average GPA in each group.

The sizes of the groups across the three grades are presented in Table 3. The first thing we observe is that the relative sizes of the groups do not change drastically across the three grades of high school. This is even more apparent in Table 4, where percentages are given instead of counts. We see, for example, that regardless of which school grade we examine, we will find that approximately 30% of the students have an excellent academic performance, while approximately 15% of the students have a very weak academic performance.

Table 3. Results of clustering in 4 clusters per academic year, based on GPA. Entries in the table indicate the count of students that has been assigned to each group.

Academic Performance Group	1st Grade	2nd Grade	3rd Grade
A	28,153	26,666	26,864
B	24,593	23,189	24,111
C	19,846	20,741	20,865
D	12,752	14,748	13,504

Table 4. Results of clustering in 4 clusters per academic year, based on GPA, expressed as percentage of the academic year's population.

Academic Performance Group	1st Grade	2nd Grade	3rd Grade
A	33%	31%	31%
B	29%	27%	28%
C	23%	24%	24%
D	15%	17%	16%

Of course, in order to assess how well the GPA predicts the future academic performance of students, it is not enough to observe that the sizes of the groups remain the same. We need to look deeper and check whether the members of the groups also remain the same. We start by examining the transition from the first to second grade. For example, in Figure 1, we present how students that had a strong academic performance in the first grade progressed in the second grade. We observe that 24504 students (67%) retained their strong performance, 33% moved to a different level of academic performance (either better or worse), and 89 students, approximately 0.4% of the latter, had a drastically different academic performance, moving to a non-neighboring academic performance group.

The results for all students, i.e., also including academic performance groups A, C, and D, are summarised in Table 5. We observe that three out of four students maintain their academic performance. More importantly, we observe that drastic changes in academic performance are extremely rare, occurring in less than half a percent of the cases.

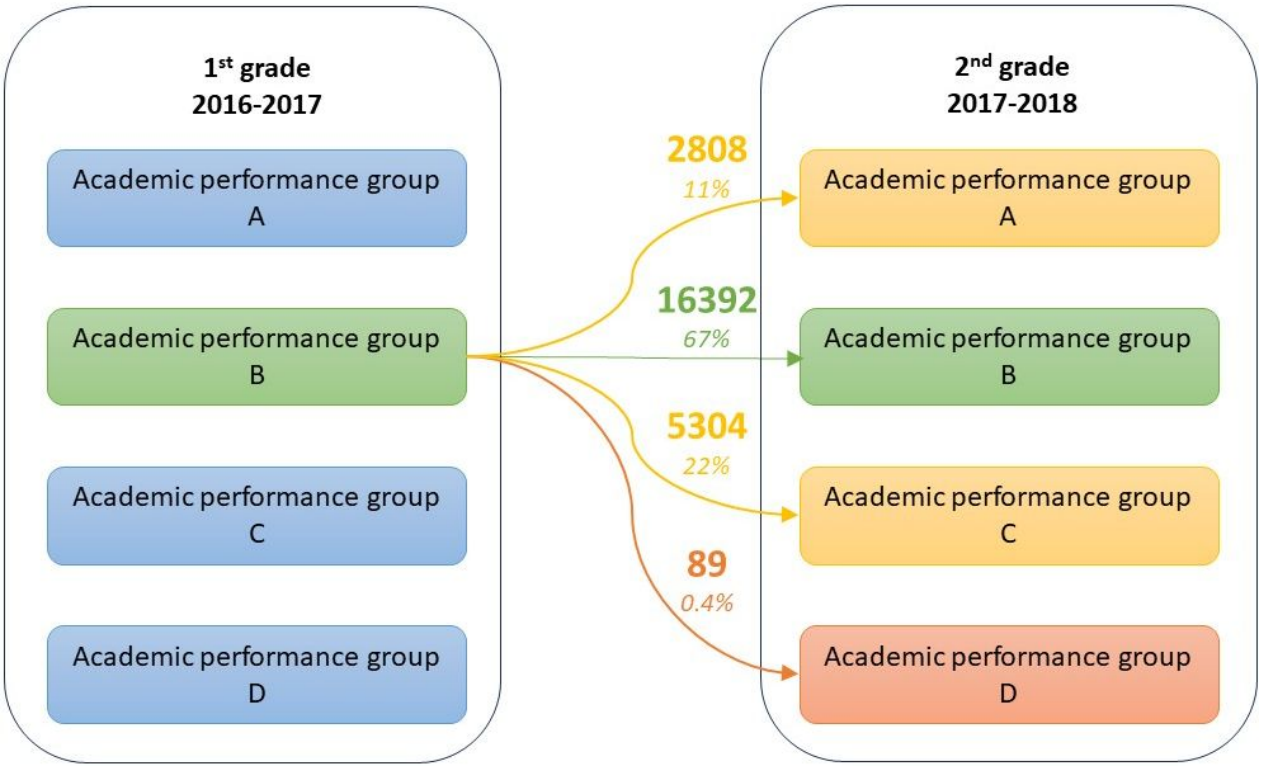

Figure 1. The progress of students with strong academic performance as they moved from the 1st to the 2nd grade of high school. Green indicates no change, yellow some change, and orange drastic change.

Table 5. Students that remained or did not remain in the same performance group when moving from the first to the second grade.

Change	Count of Students	Percentage of Students
No change	64,507	76%
Any change, small or large	20,837	24%
Drastic change	236	0.3%

But is this true in the longer term? In order to assess this, we compare the students' first grade performance to that of the third grade, as shown in Figure 2. In the figure, we see that out of the 89 students that started with a strong performance in the first grade and dropped to a very weak performance in the second grade, more than half enhanced their performance again, with some even returning to their earlier strong performance. In Table 6, we present a summary of how all students progressed through the three grades, having considered the outputs of all possible paths. We observe that more than two out of three students maintain their academic performance. More importantly, we observe that drastic changes in academic performance are still extremely rare, occurring in one percent of the cases.

Overall, based on these observations, we can conclude that the GPA is a relatively good rough predictor for the academic progress of students, both over a single year and in the longer term, as it can be used to accurately predict the group of future academic performance in the vast majority of the cases, and most importantly almost never produces severely flawed predictions.

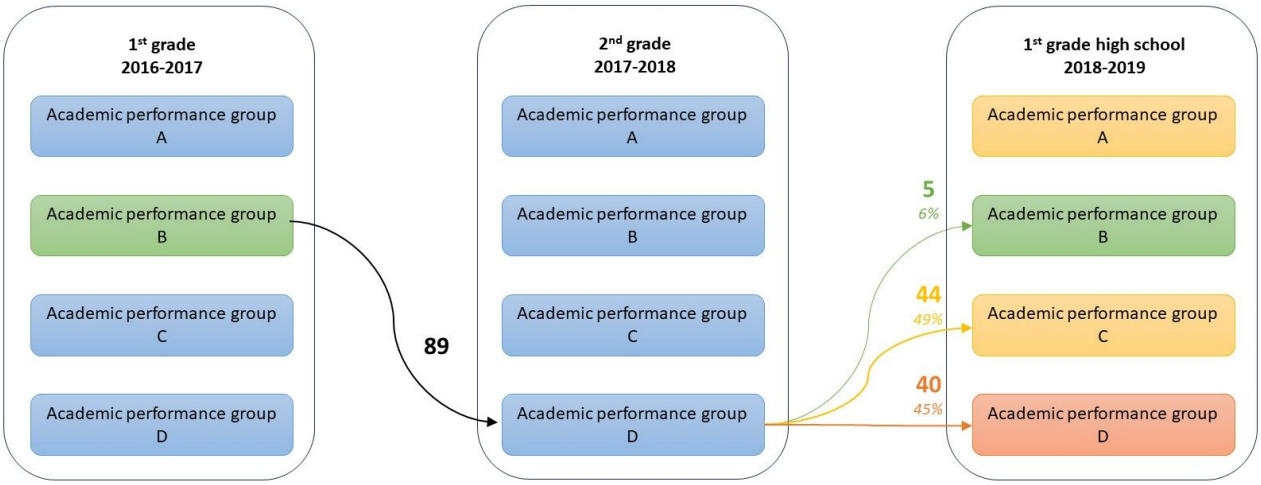

Figure 2. The progress of some of the students with strong academic performance as they moved from the 1st to the 3rd grade of high school.

Table 6. Students that remained or did not remain in the same performance group when moving from the first to the third grade. Percentages do not add exactly to 100 due to rounding errors.

Change	Count of Students	Percentage of Students
No change	59,194	69%
Any change, small or large	26,150	31%
Drastic change	886	1%

4. RQ2—Prediction of Future GPA

One can argue, of course, that the groups of academic performance are very rough descriptions and therefore that predicting the group of performance is not sufficient. In this section, we will examine to what extent the GPA can be used to predict the exact academic performance in the future, as expressed by GPAs achieved in later years.

We start by examining the progression from the first to the second grade. A first obstacle to overcome is that student performance is not scored in the same way across the different school grades. Although the same range of 0–20 marks is used throughout high school, there is a general tendency to reward effort in earlier education years and achievements in more mature years. As a consequence, high performance scores are harder to obtain as students move to higher education grades. Indicatively, in our dataset, whilst the average GPA in the first grade of high school is 17.21, for the second grade, it falls to 16.77. This means that students that maintain the same performance across the two grades can expect to see a drop of 0.44 points in their GPAs.

Taking this into consideration, for each student, we predict the second grade GPA as the GPA of the first grade reduced by 0.44. We observe that the average absolute value of the difference between the predicted and the actual second grade GPA is 0.58, with a standard deviation of 0.48 and a median value of 0.47. Clearly, the difference between predicted and actual values is minimal.

We follow the same approach in order to predict the GPA in the third grade based on the first grade GPA and calculate the absolute value of the difference between the two. We find that the average difference is 0.7 points, with a standard deviation of 0.61 and a median value of 0.52. Again, the prediction is impressively close to the actual GPA values.

Overall we easily conclude that the GPA is an excellent predictor of future academic performance as expressed by the GPA, as the GPA in the first grade can be used to accurately predict the GPA in both the immediately next grade and the one after that.

5. RQ3—Alternative GPA Calculations

By now we have established that the GPA in the first year of high school is a good predictor of academic performance in subsequent high school grades. But is it the best predictor?

Although not stated expressly in policy, in Greece, it is widely considered by teachers, students, and families alike that some courses (such as language and mathematics) are more important academically than others (such as arts or physical education). Apparently this is not particular to Greece, as the question of whether physical education should be included in the calculation of GPA has also been posed elsewhere [48]. In this section, we will examine whether a GPA that does not consider all courses equally, but rather gives more importance to some and less to others, could provide a better reflection of a student's potential and consequently an even better prediction of the student's future academic performance.

In order to estimate the relative importance of the different courses, we use the rank widget of the Orange Data Mining platform (https://orangedatamining.com/widget-catalog/data/rank/, accessed on 18 September 2023). The widget provides a variety of feature scoring methods, thus producing numerous combinations of weights. For example, in Table 7, we see the course importance weights when selecting the chi square scoring criterion. We immediately observe that the weights produced by the platform match the intuition, as on the one hand, courses that are typically considered as "core", such as Greek language and mathematics, are given the biggest scores, and on the other hand, courses such as physical education, music, and skills workshops are given the lowest scores.

Table 7. Course importance weights, as produced by the Orange platform when selecting the chi square scoring method.

Course	Importance Score
Greek Literature	39,816.79
Greek Language	44,856.70
Ancient Greek Language	48,731.50
Religious Education	35,999.96
History	40,278.44
Mathematics	46,122.55
Home Economics	36,581.78
Computer Science	23,896.15
Technology	28,216.30
Physics	39,949.40
Biology	40,398.47
Geography	39,618.01
Chemistry	42,860.60
Social and Political Education	41,787.50
Music	9186.05
Physical Education	4517.47
Skills Workshops	14,728.50
English Language	27,747.90
Second Foreign Language	33,262.49

Using the scores of Table 7 as weights, we calculate GPA^{chi^2} as the weighted average of the courses of the first grade (and similarly for the second and third grades). We then repeat the analysis of Section 3 and calculate the percentage of students that remained in the same performance group or changed performance groups when moving from the first to the second grade. Table 8 is directly comparable to Table 5 for the conventional GPA. We observe that the predictive properties of the two GPAs (the conventional one and the weighted one) are the same; if anything, the conventional GPA slightly outperforms the weighted one.

Table 8. Students that remained or did not remain in the same performance group when moving from the first to the second grade, based on GPA^{chi^2}.

Change	Count of Students	Percentage of Students
No change	63,972	75%
Any change, small or large	21,372	25%
Drastic change	271	0.3%

We repeat the process for a variety of different scoring criteria in the Orange platform (the corresponding weights are presented in Table A1 in Appendix A) and also examine the predictive properties of the different GPA metrics in both the short term (from first to second grade) and the longer term (from first to third grade). We gather all results in Table 9 in order to facilitate the comparison. In the table, we see how many students remain in the same performance group, i.e., for how many students we have a correct prediction of their future performance. We have omitted the data regarding drastic changes in academic performance, as they were negligible in all cases.

Table 9. Predictive properties of various GPA alternatives. GPA is the conventional GPA. GPA^{chi^2} is weighted based on the chi square criterion. $GPA^{infgain}$ is weighted based on the information gain criterion. GPA^{gainrt} is weighted based on the gain ratio criterion. GPA^{anova} is weighted based on the ANOVA criterion. GPA^{gainrt} is weighted based on the reliefF criterion.

Type of GPA	2nd Grade		3rd Grade	
	Count	Percentage	Count	Percentage
GPA	64,507	76%	**59,194**	**69**%
GPA^{chi^2}	63,972	75%	58,751	69%
$GPA^{infgain}$	63,933	75%	58,816	69%
GPA^{gainrt}	63,677	75%	58,670	69%
GPA^{anova}	63,858	75%	58,420	68%
$GPA^{reliefF}$	**64,780**	**76**%	58,737	69%

The weighted GPA with weights determined based on the reliefF criterion might produce slightly better predictions for the short term, but in the longer term—where it matters the most—the conventional GPA has the best performance. In any case, there is little to choose between the different approaches, and perhaps a more fair takeaway would be that they all perform equally well. Our conclusion is that none of the alternatives that we examined managed to produce substantially better predictions when compared to the conventional GPA. Therefore, our study finds no reason to revise the way in which the GPA is calculated.

6. Conclusions

In this short communication, we analysed the academic records of every student that enrolled in the first grade of high school in Greece in September 2016, and tracked their progress until the end of the third grade of high school in June 2019. This study is the first to have ever had access to a dataset containing the grades, both per subject and per year, for the complete student population of a whole country, so there are no comparable findings from other studies. In our analysis, we focused on the GPA and its ability to predict future academic performance. The specific research questions we aimed to answer were (RQ1) whether first grade GPA predicts second and third grade academic performance group, (RQ2) whether first grade GPA predicts second and third grade GPA, and (RQ3) whether an alternative calculation of the GPA might achieve better predictions.

Regarding RQ1, we found that GPA provides a reliable prediction of the future academic performance, with only 1% of students performing in the third grade drastically different to what their first grade GPA indicates. Regarding RQ2, we found that first

grade GPA is a very accurate predictor of future GPA, with an error rate that on average does not exceed 0.6 out of 20 for the second grade and 0.7 out of 20 for the third grade. Finally, regarding RQ3, having tested a variety of alternative approaches to the calculation of GPA, we found that the conventional GPA performs equally well or better than any tried alternative.

All three findings are in support of continuing to use the conventional GPA in order to assess academic potential in high school; the first two support that the GPA is a good predictor of future academic performance and the last one supports that there would be no benefit in using some alternative form of GPA.

Whereas our findings do not call for a change in the current practice, we believe they are still important for two reasons. The first one is that they are based on a quantitative analysis involving the full student population of a whole country. Thus, we no longer have a mere intuitive feeling about the value of the GPA, but instead, a very reliable (via the sheer volume of the dataset) quantitative confirmation of its predictive properties. The second is that our findings contradict an intuitive expectation, emphatically rebutting the expectation that a weighted GPA that puts more emphasis on core courses and less on courses often deemed as secondary would be more representative of a student's potential.

6.1. Limitations

A limitation of our study is that it has been based on data derived exclusively from the Greek education system. Therefore, our findings might be particular to the case of Greece. Further research is needed in order to establish whether similar findings hold true for other countries, especially those that have educational systems that are structured differently than that of Greece.

6.2. Future Research

Having established that GPA is a meaningful metric in high school, as part of our future work, we plan to examine whether the same holds true for earlier stages of education. In the Greek educational system, numerical grades and GPA first come into play at the fifth grade of elementary school. As a next step, we shall examine the records of all fifth graders and track their progress through high school, aiming to establish whether there is an equally strong correlation between GPA in elementary school and later academic performance.

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Conflicts of Interest: I.P. is Head of Administrative Directorate of the Regional Education Directorate of Peloponnese. The other authors declare no conflict of interest.

Appendix A. Course Weights Used in the Calculation of Weighted GPA Scores

Table A1. Courses' weights, as calculated by the Orange platform using different scoring options.

Lesson	chi^2	Inf. Gain	Gain Ratio	ANOVA	reliefF
Greek Literature	39,816.80	0.693016	0.350941	52,476.20	0.090410
Greek Language	44,856.70	0.670554	0.336379	48,928.90	0.082805
Ancient Greek Language	48,731.50	0.703587	0.361261	52,657.10	0.089857
Religious Education	35,999.96	0.486662	0.249384	29,996.70	0.072567
History	40,278.40	0.682574	0.344007	55,619.80	0.090181
Mathematics	40,398.50	0.601192	0.304467	44,838.70	0.083461
Home Economics	36,581.80	0.488409	0.250016	30,264.70	0.081459
Computer Science	23,896.10	0.313992	0.160368	15,433.20	0.032100
Technology	28,216.30	0.334923	0.222179	16,125.40	0.030976
Physics	38,961.90	0.545619	0.273215	38,949.40	0.038838
Biology	54,942.50	0.676912	0.339833	41,617.60	0.105455
Geography	39,618.00	0.585534	0.294713	42,298.20	0.098573
Chemistry	57,506.50	0.690078	0.346513	42,860.60	0.107945
Social and Political Education	41,787.50	0.582667	0.291426	38,393.70	0.092651
Music	24,156.20	0.240835	0.157425	9186.05	0.043716
Physical Education	4517.47	0.068420	0.079009	1072.91	0.003324
Skills Workshops	14,728.50	0.279432	0.187594	10,529.20	0.045207
English Language	27,747.90	0.402294	0.204230	23,218.20	0.068469
Second Foreign Language	33,262.50	0.463334	0.231998	26,867.00	0.043972

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