# Project Report for Data Literacy 2023/24
# Grade Inflation in the German School System - Causes and Effects

**Jonathan Schwab** [*1] **Lars Kasüschke** [*2] **Niklas Munkes** [*3] **Tom Freudenmann** [*4]

## Abstract

The steady increase in Abitur grades indicates grade inflation in German schools. This study analyzes the factors influencing the children's performance in the German school system through an exploratory data analysis. Examining variables such as student numbers, teacher ratios, repeaters, and budget per child, the research aims to both describe and correlate these factors. The findings challenge the idea that grade inflation is the only cause of rising grades and emphasize the importance of having a small students-per-teacher ratio.

## 1. Introduction

The Abitur grades have constantly increased in the German school system over the past years (Kultusminister Konferenz), resulting in a research discussion in the media. The main topic of discussion is whether grades get better, even if students performance decreases.

The discourse has predominantly centered around mathematics, since the difficulty of exercises is easiest to compare. On the one hand, mathematicians argue that there is grade inflation in Germany, i.e., that results are improved by easier tasks and not by smarter children (Kühnel, 2015; Jahnke et al., 2014; Lemmermeyer et al., 2019). On the other hand, there are studies claiming that grade inflation cannot be reliably proven since the competence of students has also increased (Schleithoff, 2015).

In 2015, a data-driven approach was employed by Grözinger & Baillet, involving the analysis of comprehensive data on the education system. The results were promising, but not yet enough to dismiss the claim of grade inflation.

This paper expands on that work, challenging the claim that grade inflation is the main cause of the upward trend in Abitur grades in the German education system. Building upon publicly available data, an analysis is conducted to provide insights into causes and effects on the schoolchildren's performance[1].

Moreover, this study investigates whether there are any quantifiable causes of the rising Abitur grades. In addition, the causes and evolution of the repeater ratio and the budget per child across all federal states are investigated to project the results to other educational institutions.

## 2. Methods

This section explores the data set and describes the mathematical concepts to from quantitative arguments on the introduced questions.

### 2.1. Datasets

This paper investigates both the causes and effects of the phenomena discussed in section 1. Thus, the analyzed datasets are grouped into *cause* and *effect* datasets. Therefore, this study defines *causes* as the social, demographic, or political factors that influence the German school system, such as the number of students, teachers, or budget provided by the German government. Instead, *effect* refers to the observable impact of these causes on any measure modeling the students' performance, e.g., average grades or the rate of repeaters and school-leavers. All data sets used are collected in all public schools, since they are obliged to forward them to the federal statistical institutions (Statistische Bundesamt, 2024; Kultusminister Konferenz).

Firstly, the dataset *Fachreport Schuljahr 2020/21* contains the number of teachers from 1992 until 2020 (Statistische Bundesamt, 2022). The dataset is grouped into teacher's contract type, federal state, and school type. In addition, the number of schoolchildren is analyzed with two additional datasets (Statistische Bundesamt, 2024). The first dataset

[*]Equal contribution [1]Matrikelnummer 6765897, jonathan.schwab@student.uni-tuebingen.de, MSc Computer Science [2]Matrikelnummer 4247775, lars.kasueschke@student.uni-tuebingen.de, BSc Computer Science [3]Matrikelnummer 4269436, niklas.munkes@student.uni-tuebingen.de, MSc Media Informatics [4]Matrikelnummer 6631101, tom.freudenmann@student.uni-tuebingen.de, MSc Computer Science.

*Project report for the "Data Literacy" course at the University of Tübingen, Winter 2023/24 (Module ML4201).* Style template based on the ICML style files 2023. 

[1]Source files are publicly available in the project repository.

(21111 − 0002) contains the number of children per grade and school type for the years 1998 to 2022. The second (21111 − 0010) provides the absolute number of children, leavers, and beginners in each federal state from 1997 to 2022. Thus, the analysis can only be conducted separately for both school types and federal states, as they are not incorporated in the same table and cannot be merged.

Additionally, this paper considers the budget per child (21711 − 0011) as a possible cause, which is provided by the Statistische Bundesamt. The dataset contains the budget per child for the years 2010 to 2022 and is grouped by federal states. To adjust for inflation, the budget is multiplied with the *Verbraucherpreisindex* (61111 − 0010) relative to 2022, as provided by the Statistische Bundesamt.

Furthermore, it is also important to analyze the effects on student performance, since they are the first indicator of whether grade inflation exists. One of the few publicly available datasets containing grades are the average Abitur grades per federal state. The grades are published every year in separate reports by the Kultusminister Konferenz. Each file contains the count of children per written grade and federal state. The grades range from 1.0 (best) to 4.0 (worst) in increments of 0.1. The number of children who failed with a grade worse than 4.0 is aggregated in an additional column.

While this is a feasible variable for the performance of children attending grammar schools, a general performance measure for all school types is required to translate the results. Accordingly, the dataset (21111 − 0014) of the Statistische Bundesamt provides the number of repeaters by federal state, school type, and year from 1998 to 2022.

### 2.2. Mathematical Concepts

The subsequent paragraph provides an overview of the two primary concepts used in this paper: *linear regression* and the Pearson *correlation coefficient*.

Linear regression is a statistical technique for modeling the relationship between a dependent variable $Y$ and one or more independent variables $X_1, ..., X_p$ (James et al., 2021). It seeks to fit a linear equation to the data that minimizes the discrepancy between observed and predicted values. This is done through least squares minimization, resulting in an equation of the form (James et al., 2021):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_p X_p + \epsilon \qquad (1)$$

The Pearson correlation coefficient $r$, is a statistical measure used to assess the linear relationship between two sets of data, $X$ and $Y$ (Rodgers & Nicewander, 1988). It is defined as the ratio of the sample covariance of $X$ and $Y$ to the product of their sample standard deviations (Rodgers & Nicewander, 1988):

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2 \cdot \sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \qquad (2)$$

### 2.3. Exploratory Data Analysis

Having introduced all used datasets and primary mathematical concepts, this paragraph investigates possible patterns through an exploratory data analysis of the potential *causes* and *effects*.

First, the demographic effects on the number of children attending school and the number of teachers employed by school type and federal state are considered. The exploratory data analysis of the teachers and children datasets[2] has shown that the number of schoolchildren decreased steadily from 1998 to 2014. Instead, it increased from 2019 to 2022 because more children started their education and fewer left school. Furthermore, there is an overall trend of more children graduating from grammar schools with university entrance qualifications.

Moreover, these demographic effects are combined with an increasing number of teachers across German school types and federal states. Although, there is a difference between old and new federal states in the evolution of full- and part-time teachers, as displayed in Figure 1. The new federal states had a higher proportion of part-time teachers than full-time teachers between 2004 and 2008. Instead, the old federal states have a nearly constant distribution of part-time teachers on average. Furthermore, they have employed fewer full-time teachers since 2014 than the new federal states.

Given the hypothesis that having more teachers per student increases the quality of teaching, the datasets are merged to explore their relationship (Kasau Onesmus Mulei et al., 2016; Koc & Celik, 2015). As explained in subsection 2.1, this merge can only been done separately for school types and federal states. Furthermore, the students-per-teacher ratio is calculated over full- and part-time teachers, since they represent the majority ($\sim 90\%$) of the distribution (Figure 1). As a result, the average of the 5 most common schools decreases from 29 to 24 students-per-teacher. Together with the hypothesis, it follows that the quality of teaching will increase, and thus the performance measures will increase.

Besides the demographic measures, the analysis of the adjusted budget[3] to inflation per child has shown that it steadily increases for all federal states. Although, this may be caused by the increasing number of teachers and the goals of digitalization in schools in the last few years (Cone et al., 2022).

[2] Teachers and children plots and exploration can be found here.

[3] Budget plots and exploration can be found here.

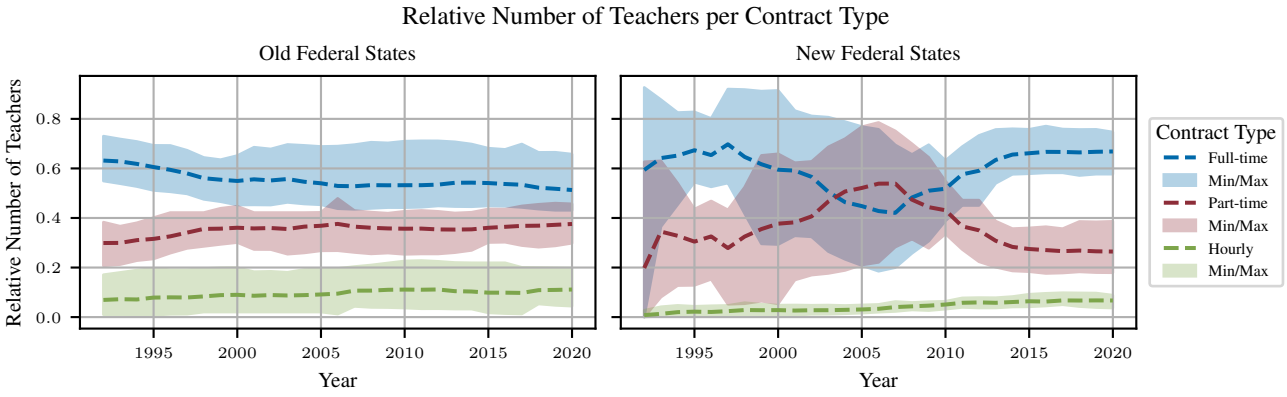


*Figure 1.* Relative number of teachers by contract type and federal states. The average ratio of full-time (▬ ▬), part-time (▬ ▬) and hourly-based (▬ ▬) contracts of teachers is displayed with its minimal and maximal bound for the old federal states (*left*) and the new federal states (*right*).

Now that some basic effects that may influence the students' performance have been identified, it is possible to study the performance measures. As the analysis of the students' datasets[2] has shown, more children are attending grammar schools in Germany. Thus, the average Abitur grade of the children is a feasible measure of the performance of many children. The analysis results of the Abitur grades[4] are shown in Figure 2. Importantly, the regression between grades and years is calculated on the Abitur data[4] before 2021 because of the COVID-19 pandemic beginning in 2020. In 2022, the grades significantly increased compared to the years before the pandemic. This could indicate that the pandemic has had new consequences for the educational system. Due to the lack of data following the pandemic, this paper will focus on the linear trend until 2020. Furthermore, an additional analysis[4] of the relative number of failed students has shown that the failure rate has no repetitive or linear pattern. Thus, the provided results in Figure 2 are only valid for children graduating with a grade of at least 4.0.

Moreover, children attending other schools have no direct impact on the results of the Abitur grades. Therefore, the number of repeaters per federal state, school type, grade, and school year is analyzed. To enhance the relevance of the results, the relative ratio of repeaters[5] is calculated by dividing the absolute counts by the absolute number of schoolchildren. This results in an aggregation for the federal states per year and in one for the school types per year. As a result, the number of repeaters has decreased for all educational institutions and federal states from 1998 to 2020. Hence, the trend equals the expected result, after analyzing the Abitur grades.

The exploratory findings indicate an increasing number of students and teachers, resulting in a decreasing ratio of students to teachers and a rise in the budget per child. The possible outcomes include a linear increase in Abitur grades in grammar schools and a shrinking proportion of repeaters in general.

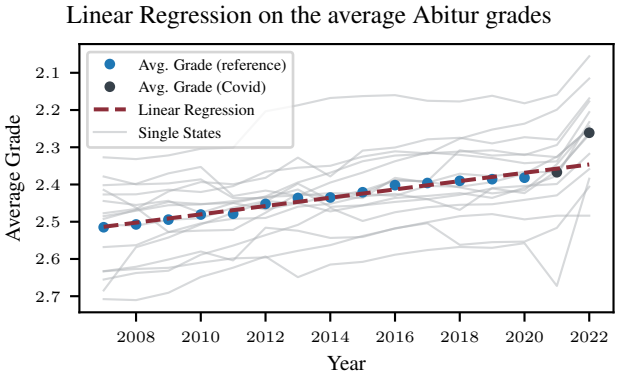


*Figure 2.* Average Abitur grades before (●) and after the COVID-19 pandemic (●) with a linear regression line (▬ ▬) of the years 2007 to 2020. In the background, the figure contains average grades for each federal state (_).

## 3. Results and Discussion

The introduced students-per-teacher ratio aggregates the number of children per teacher, either for each federal state or school type. This section will compare it to the Abitur grades, repeaters, and budgets. Due to the data representation, the Abitur grades can only be analyzed for the German average. Nevertheless, the repeaters and budgets are analyzed for each federal state.

One of the key findings of this analysis is the strong correlation between the average grades across all federal states and the students-per-teacher ratio in German grammar schools. As shown in Figure 3, the relationship between both is

[4] Abitur plots and exploration can be found here.
[5] Repeater plots and exploration can be found here.

nearly linear and contains neither clusters nor outliers. Thus, a smaller students-per-teacher ratio strongly correlates to better Abitur grades, with a Pearson correlation coefficient of $r = 0.98$.

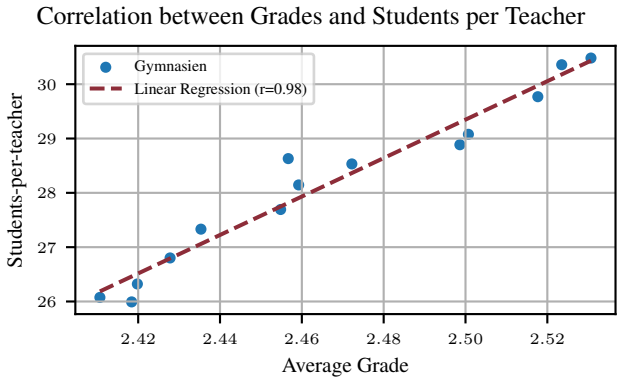


*Figure 3.* Linear regression on the students-per-teacher ratio by average Abitur grade. The resulting regression line (▬) is calculated over the aggregated average overall grammar schools (●) in Germany.

This confirms the initial hypothesis of the high influence of the students-per-teacher ratio on grades and is consistent with the findings of prior research (Kasau Onesmus Mulei et al., 2016; Koc & Celik, 2015; Dickson, 1984).

However, the Abitur grades only give an insight into grammar schools. So additionally, the correlations with repeaters and budgets are shown in Figure 4. Note, that the Pearson correlation coefficients for each state are normalized to the used color map scale.

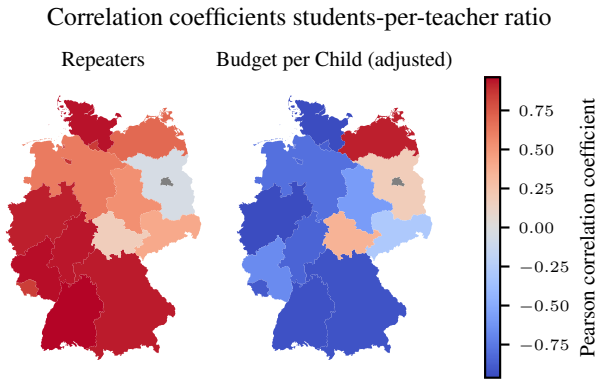


*Figure 4.* Pearson correlation coefficients between the students-per-teacher ratio and the relative repeater count (left) and the inflation-adjusted average budget per child (right). Missing values are shown in dark gray.

The findings presented in Figure 4 support a positive correlation between the students-per-teacher ratio and the number of repeaters in most federal states. In contrast, the right heatmap (Figure 4) indicates a negative correlation between the students-per-teacher ratio and budget per child for the same states. Furthermore, there is a big difference between *old* and *new* federal states for both correlations. Especially, the results for Thüringen and Brandenburg diverge from the average in both maps. Rather, Mecklenburg-Vorpommern differs most in the budget per child from the other states.

However, an increase in the number of students in the new federal states can explain the different correlations in the budget per child[2]. Since the per-child budget has increased in all states[3], the schools got more money in total. This results in more vacancies at schools (Kultusminister Konferenz, 2023) and other investments, like digitalization and maintenance of schools (Bundesministerium für Bildung und Forschung, 2022). But in the short term, there will be more teachers needed as available (Kultusminister Konferenz, 2023). As Figure 1 indicates, this leads to a high variance in the distribution of teacher contract types, especially for the new federal states. This results in a higher students-per-teacher ratio with the same budget.

In contrast, the anomaly for the repeaters involves more aspects of the educational system, like the different curricula or conditions for repeating a class. The conditions for repetitions vary between federal states and are just an indicator rather than a measure of educational quality (Klemm, 2009). Hence, a complete explanation for these results involves more datasets and effects. Although, the majority of federal states have a positive correlation with the number of repeaters, it indicates that a small students-per-teacher ratio is beneficial for challenged students.

Moreover, the other states indicate that a higher budget per child results in a smaller students-per-teacher ratio. Hence, the number of repeaters decreases with the students-per-teacher ratio.

## 4. Conclusion

This exploratory data analysis found correlations between the ratio of students and teachers, Abitur grades, repeaters, and budget-per-child. These indicate the importance of employing enough teachers, to increase children's performances. Prognoses are showing that there are still more open positions than teachers available (Kultusminister Konferenz, 2023). Fortunately, the Kultusminister Konferenz predicts that this gap will eventually close in the coming decade.

Furthermore, the absence of teachers has an influence on the Abitur grades. It is evident from the observed correlations that the grades should get worse in the short term and increase in the long term, if there are no other factors influencing the Abitur grades. All in all, this analysis shows that grades at schools do not only rise due to grade inflation, but are also influenced by other positive factors.

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