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Report of developing Learningtower R package

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1 Abstract

The learningtower R package offers a simplified method for examining data from the 2000–2022 Programme for International Student Assessment (PISA). The Organisation for Economic Co-operation and Development (OECD) administers PISA, a triennial international study that assesses educational systems around the world by assessing 15-year-old students' reading, math, and science proficiency. The learningtower package, which focusses on important aspects like gender disparities, socioeconomic impacts, and temporal trends in student performance, provides tools for data curation, visualisation, and statistical modelling. It is intended to enhance educational research and policy creation. Learningtower helps users gain insights into global educational performance and inequities across nations by making PISA data more easily available and workable.

2 Background

The learningtower package, which focusses on school and student-level data like performance indicators, socioeconomic backgrounds, and educational resources, contains educational datasets from international exams like PISA before 2022. After being cleaned and standardised, these datasets go through modifications including variable alignment for consistency and student-teacher ratio calculations. Key performance indicators include student performance in disciplines including reading, mathematics, and science; school and country identities; and educational resources (e.g., staff shortages, school size). The information makes it possible to analyse regional and worldwide trends as well as differences in educational systems, which sheds light on the variables influencing resource allocation and academic performance.

3 Introduction

With an emphasis on the Programme for International Student Assessment (PISA) data from 2000 to 2022, the learningtower package is an effective tool for analysing data on education around the world. Every three years, the OECD administers PISA, which evaluates 15-year-old students' proficiency in reading, arithmetic, and science to gauge their capacity to apply knowledge to real-world issues. This enables nations to track changes in schooling over time. Although PISA data can be found on the OECD website, its complicated structure and variety of formats make it difficult to analyse. These problems are addressed by the learningtower package, which integrates complete data on student performance, school resources, teacher-student ratios, and socioeconomic factors while cleaning, standardising, and preparing the data for extensive cross-sectional and longitudinal research. The program now provides the most recent information on worldwide educational trends thanks to the recent addition of the

2022 dataset, allowing for thorough cross-national comparisons and assessments of the variables affecting student results.

3.1 PISA

The Organization for Economic Cooperation and Development OECD is a global organization that aims to create better policies for better lives. Its mission is to create policies that promote prosperity, equality, opportunity, and well-being for all. (Organization for Economic Cooperation and Development 2021a) PISA is one of OECD's Programme for International Student Assessment. PISA assesses 15-year-old students' potential to apply their knowledge and abilities in reading, mathematics, and science to real-world challenges. OECD launched this in 1997, it was initially administered in 2000, since the year 2000, it has involved more than 100 countries and economies and has conducted tests of more than 3.7 million students worldwide.(https://www.oecd.org/pisa/aboutpisa/pisa-participants.html).(Organization for Economic Cooperation and Development 2021b) The PISA study, conducted every three years, provides comparative statistics on 15-year-old students' performance in reading, math, and science. This report describes how to utilize the `learningtower` package, which offers OECD PISA datasets from 2000 to 2022 in an easy-to-use format. The datasets comprise information on students' test results and other socioeconomic factors, as well as information on their schools, infrastructure and the countries participating in the program.

3.2 Learningtower Package

'learningtower' The R package (Wang et al. 2021) provides quick access to a variety of variables in the OECD PISA data collected over a three-year period from 2000 to 2022. This dataset includes information on the PISA test scores in mathematics, reading, and science. Furthermore, these datasets include information on other socioeconomic aspects, as well as information on their school and its facilities, as well as the nations participating in the program.

The `learningtower` package primarily comprised of three datasets: `student`, `school`, and `countrycode.` The `student` dataset includes results from triennial testing of 15-year-old students throughout the world. This dataset also includes information about their parents' education, family wealth, gender, and presence of computers, internet, vehicles, books, rooms, desks, and other comparable factors. Due to the size limitation on CRAN packages, only a subset of the student data can be made available in the downloaded package. These subsets of the student data, known as the `student_subset_yyyy` (`yyyy` being the specific year of the study) allow uses to quickly load, visualise the trends in the full data. The full student dataset can be downloaded using the `load_student()` function included in this package. The `school` dataset includes school weight as well as other information such as school funding distribution, whether the school is private or public, enrollment of boys and girls, school size, and similar other characteristics of interest of different schools these 15-year-olds attend around the world. The `countrycode` dataset includes a mapping of a country/region's ISO code to its full name.

4 Goals

The motivation for developing the `learningtower` package was sparked by the announcement of the PISA 2018 results, which caused a collective wringing of hands in the Australian press, with headlines such as "Vital Signs: Australia's slipping student scores will lead to greater income inequality" and "In China, Nicholas studied math 20 hours a week. In Australia, it's three". That's when several academics from Australia, New Zealand, and Indonesia decided to make things easier by providing easy access to PISA scores as part of the ROpenSci OzUnconf, which was held in Sydney from December 11 to 13, 2019.

The data from this survey, as well as all other surveys performed since the initial collection in 2000, is freely accessible to the public. However, downloading and curating data across multiple years of the PISA study could be a time consuming task. As a result, we have made a more convenient subset of the data freely available in a new R package called `learningtower`, along with sample code for analysis.

`learningtower` developers are committed to providing R users with data to analyse PISA results every three years. Our package's future enhancements include updating the package every time additional PISA scores are announced. Note that, in order to account for post COVID-19 problems, OECD member nations and associates decided to postpone the PISA 2021 evaluation to 2022 and the PISA 2024 assessment to 2025.

5 Compiling the data(more details about the process and problems faced)

We are responsible for the curation of the newest PISA study, year 2022. data on the participating students and schools were first downloaded from the PISA website, in either SPSS or SAS format. The data were read into an R environment. After some data cleaning and wrangling with the appropriate script, the variables of interest were re-categorised and saved as RDS files. One major challenge faced by the us was to ensure the consistency of variables over the years. However, several variables may be missing due to the reconstruction of questionnaires. For instance, a question regarding student's possession of desk is not recorded in 2022, but it was included in previous questionnaires, hence these variables were manually curated as an character variable in the output data. Another important issue we faced is a missing variable `WEALTH`, this variable used to be a good measurement of a student's socioeconomic status. But we also discovered a variable called `ESCS` (economic, social and cultural status). These final RDS file for each PISA year were then thoroughly vetted and made available in a separate GitHub repository.

6 Communication and Documentation Tools

Slack and Notion can be effectively utilized together to enhance team communication and documentation management. Slack serves as a real-time communication tool, allowing teams to quickly exchange information, discuss projects, and stay updated on tasks, making it ideal for team collaboration.

Notion, on the other hand, excels as a centralized workspace for recording and organizing important documents, such as meeting journals, project notes, and other key materials, ensuring that important information is organized and easily accessible.

By using Slack for dynamic conversations and Notion for structured documentation, teams can ensure seamless communication while maintaining an organized record of all important documents, meeting notes, and long-term planning.

7 Overview of the data

7.1 Student Dataset

The dataset offers student-level information from a number of nations and captures variables that affect academic performance. it contains the 23 variables, which could be categorized into groups:

Year: represents the year of data collection, which is manually constructed by the contributor.

Country: specifies the country from which the student data has been collected, using country codes.

School's inforamtion: represents the unique identifier of each student's school.

Student's inforamtion: This group provides some information about each student in the dataset.

1. **Parent's education**: record the parent's highest level of education based on the International Standard Classification of Education (ISCED) levels, ranging from "less than ISCED1" to "ISCED 3B, C".
2. **Gender**: categorizes the gender of each student as "male" or "female".

3. **Household possession**: record several variables related to students' household resources. Including whether the student has access to a computer and internet at home, both marked as "yes" or "no." Additional household resources are indicated by variables for a desk, separate room, dishwasher, television, and car. The number of computers and laptops is also available. Finally, the number of books in the student's home is categorized into ranges, such as "0-10" or "101-200.

4. **Math, Read, Science**: These columns provide the scores in mathematics, reading, and science subjects, respectively.

5. **Stu_Wgt**: Represents the student weight, used for calculating weighted averages in the analysis to ensure representative data.

6. **Wealth**: This column provides a measure of the student's economic wealth, where higher values indicate greater wealth. However this variable is not recorded in 2022 dataset.

7. **ESCS**: Represents the Economic, Social, and Cultural Status index, which is a composite measure of a student's socio-economic background.

7.2 School Dataset

The school dataset covers a variety of educational topics and offers data about schools across multiple nations.

year: Year represents the year during which the data was collected.

country: Country refers to the countries from which the data was collected.

School's information:

1. **school_id**: A unique identifier for each school, allowing for consistent tracking of school-related data across different records and years.

2. **public_private**: Designates the type of school administration, distinguishing between public (government-funded) and private (independently funded) institutions.

3. **stratio**: Represents the student-teacher ratio, indicating the average number of students per teacher in the school. Lower ratios typically suggest smaller class sizes and potentially more individualized attention.

4. **staff_shortage**: A measure indicating the level of staffing challenges faced by the school. Positive values may suggest severe shortages, while negative values or zeros may indicate minimal issues.

5. **school_size**: The total number of students enrolled, which can reflect the school's capacity and influence on the learning environment. Larger schools may offer more diverse programs, while smaller ones might provide a more personalized setting.
6. **fund_gov**: the percentage of funding that the government provides to the school. Understanding the resources available for staffing, programs, and infrastructure can be greatly aided by this.
7. **fund_fees**: The proportion of money that came from student fees demonstrates the school's reliance on fee-based revenue, which is more usual in private institutions.
8. **fund_donation**: represents the proportion of funds raised through donations, which could be a sign of extra support systems or community involvement.
9. **sch_wgt**: In order to guarantee that the sample appropriately reflects the school population, school weight is utilised in statistical analysis, especially in weighted averages or survey data.

7.3 Countrycode Dataset

This dataset includes a mapping of a country/region's ISO code to its full name. More information on the participating countries can be found here.

8 Analysis

In this section we will illustrate how the `Learningtower` package can be utilized to answer some research questions by applying various methodologies and statistical computations on the `Learningtower` datasets.

We will solely utilise the 2022 PISA data and scores for illustrative purposes throughout the analysis section. Some of these questions include if there is any significant gender difference between girls and boys and explore their performance in the areas of mathematics, reading, and science. Furthermore, we will inspect the various socioeconomic characteristics reflected in the student data and investigate if they have any substantial impact on the scores of these students.

8.1 Gender Gap

Gender gaps have always been a topic of interest among researchers, and when it comes to PISA data and scores of 15-year-old students around the world, uncovering patterns based on their gender would help gain meaningful insights in the field of education for various education policymakers around the world. Based on the 2022 PISA results, let us see if there is a major gender disparity between girls and boys throughout the world in mathematics, reading, and science. To begin, we will create a 'data.frame' that stores the weighted average math score for each nation as well as the various regions of the countries grouped by country and gender, in order to create this `data.frame` and represent data in the tidy format we use the `tidyverse` (Wickham et al. 2019) R package. Survey weights are critical and must be used in the analysis to guarantee that each sampled student accurately represents the total number of pupils in the PISA population. In addition, we compute the gender difference between the two averages. To demonstrate the variability in the mean estimate, we use bootstrap sampling with replacement using the `map_dfr` function on the data and compute the same mean difference estimate. For each country, the empirical 90 percent confidence intervals are presented. The same process is used for reading and science test scores.

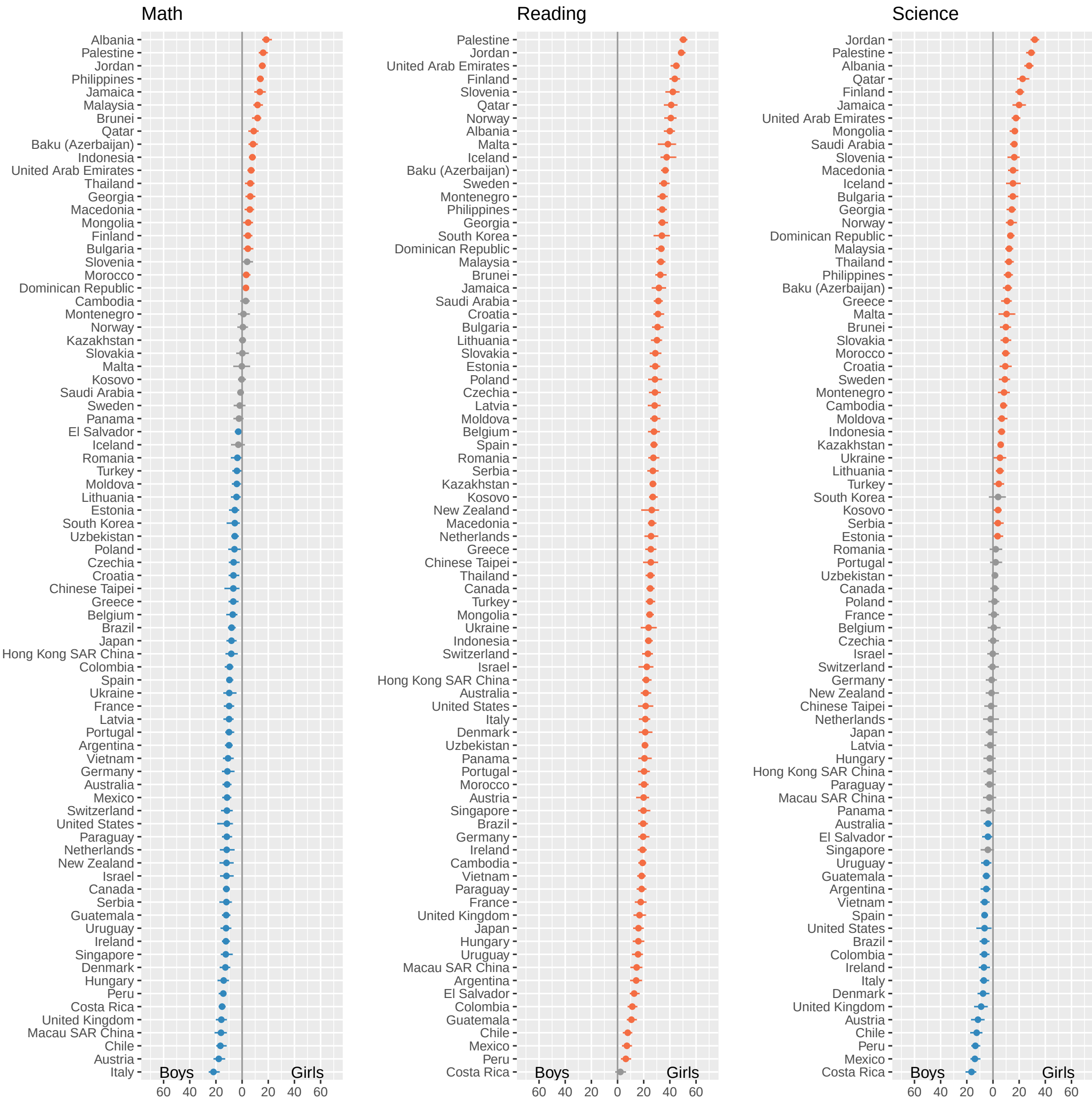


Figure 1: *The chart above depicts the gender gap difference in 15-year-olds' in math, reading, and science results in 2022. The scores to the right of the grey line represent the performances of the girls, while the scores to the left of the grey line represent the performances of the boys. One of the most intriguing conclusions we can get from this chart is that in the PISA experiment in 2022, girls from all countries outperformed boys in reading.The chart above depicts the gender gap difference in 15-year-olds' in math, reading, and science results in 2022. The scores to the right of the grey line represent the performances of the girls, while the scores to the left of the grey line represent the performances of the boys. One of the most intriguing conclusions we can get from this chart is that in the PISA experiment in 2022, girls from all countries outperformed boys in reading.*

Figure 1 illustrates the global disparities in mean math, reading, and science outcomes, before we get to the plot conclusion, let's have a look at the variables that have been plotted. The grey line here indicates a reference point, and all of the scores to the right of the grey line show the scores of girls in math, reading, and science. Similarly, the scores on the left side of this grey line indicate the scores of boys in the three disciplines. Based on Figure 1, because most math estimates and confidence intervals lie to the left of the grey line, we may conclude that most boys outperformed girls in math.

In nations such as Panama, Malta, Saudi Arabia, Sweden, Kazakhstan, Norway, Slovenia, Iceland, Kosovo, Cambodia, Montenegro and Slovakia, there is almost no gender difference in average math scores. When we look at the reading scores, we notice a remarkable trend in that all girls outpaced boys in reading in all countries in 2022. The highest reading scores were achieved by girls from Palestine, Jordan and United Arab Emirates. Looking further into the science plot, we see an unexpected pattern here where most countries have very little gender difference in science scores, implying that most boys and girls perform equally well in science. Boys from Costa Rica, Mexico and and Peru perform well in science and girls from Jordan, Palestine, and Albania are the top scores for science. Figure 1 helps us to depict the gender gap in math, reading, and science for all nations and regions that took part in the 2022 PISA experiment.

We gathered meaningful insights about the gender gap between girls and boys across the world from the above Figure 1 because this is a geographical research communication topic, the findings will help us better comprehend the score differences in the three educational disciplines using world maps. Let us continue to investigate and discover patterns and correlations using map visualization. To illustrate the gender gap difference between girls and boys throughout the world, we summarize regions on a country level and utilize the `map_data` function to get the latitude and longitude coordinates needed to construct a map for our data. We connect these latitude and longitude coordinates to our PISA data and render the world map using the `geom_polygon` function wrapped within `ggplot2` (Wickham 2016), the interactive features and placement of the plots are made using `plotly` (Sievert 2020) and `patchwork` (Pedersen 2020) packages in R.

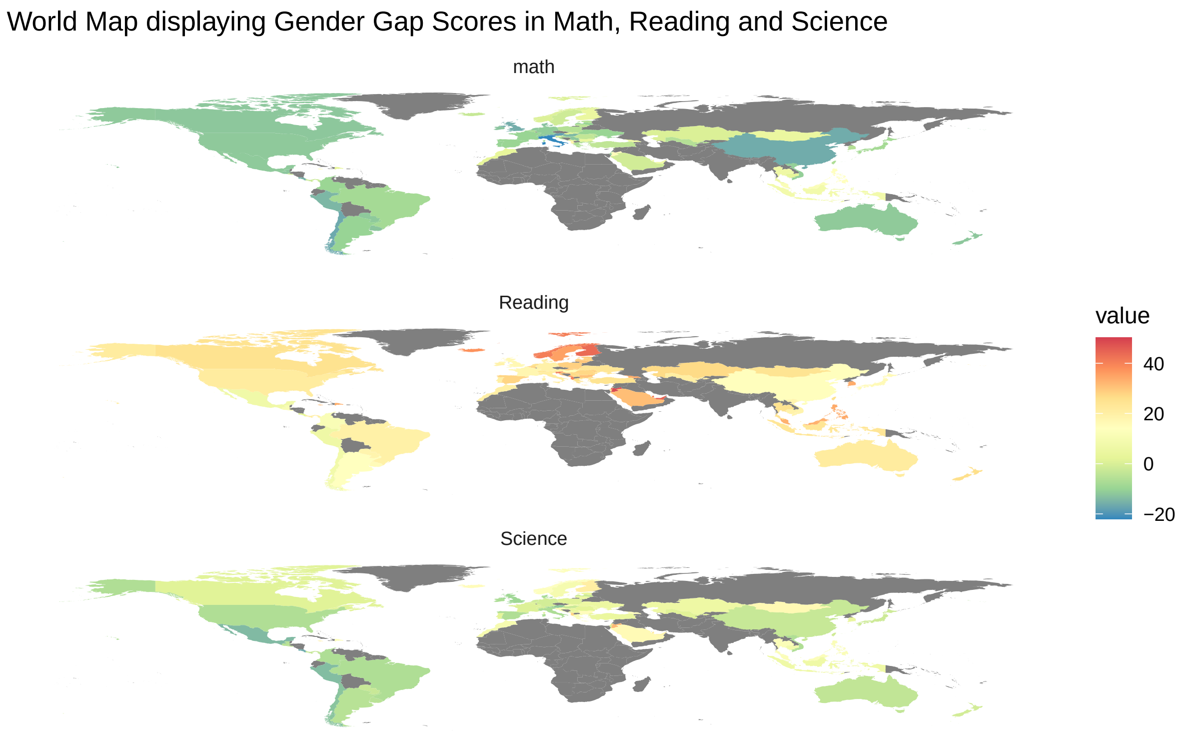


Figure 2: *Maps showing the gender gap in math, reading, and science results between girls and boys across the world. A positive score for a country indicates that girls outperformed boys in that country, whereas a negative score for a country difference indicates that boys outperformed girls in that country. The diverging colour scale makes it possible to interpret the range of scores and the also helps us intrepret the gender gap difference among these students across the globe.*

In the Figure 2, we have shown the gender gap difference between girls and boys in math, reading, and science in 2022. Map visualization aids in the comprehension of large volumes of data in a more efficient manner and increases the ability to compare outcomes across many geographical locations at a glance. In this figure, we see both positive and negative score difference scale ranges in all three maps. A positive country score indicates that girls outperformed boys in that country, whereas a negative country score shows that boys outscored girls in that country. The diverging spectral color scale and the legend of these maps makes it possible for us to deduce and identify regions across the globe showing large gender discrepancy between girls and boys. The grey colour for different geographic locations across the maps in Figure 2 indicates that these regions were not a part of the PISA experiment in year 2022.

Even though the map visualization embeds the same scores as Figure 2, one of the most striking thing on this map is the lack of data for the Africa continent. We see that there is less of a gender disparity seen in the science scores compared to maths and reading. In addition, the color scale for scores of each subject aids in identifying the countries that took part in the PISA experiment. As a result, in this section, we have seen the gender gap scores and striking trends between 15-year-old girls and boys in math, reading, and science. Our main conclusion from this gender study is the performance of girls in reading. The fewer gender disparity is evident in the science scores, and the majority of boys perform better than girls in mathematics.

9 Socioeconomic factors

Socioeconomic status is an economic and sociological complete measure of a person's work experience, economic access to resources, and social standing in relation to others. Do these socioeconomic factors influence students' academic performance? In this section, we will investigate if different socioeconomic factors owned by a family have a significant impact on a student's academic performance. The student dataset in the `learningtower` package contains scores of 15-year-olds from triennial testing across the world. This dataset also includes information about their parents' education, family wealth, gender, and ownership of computers, internet, cars, books, rooms, desks, and dishwashers. Next, we will mainly explore some fascinating aspects of the influence of a few socioeconomic factors on student performance in math, reading, and science. Let us further explore the impact of a selection of socioeconomic factors on the students' score.

Parents qualification is a vital element of childhood development. As previously stated, the student dataset in the package includes information regarding the parents qualification. In this section, we will investigate if both the mother's and father's qualifications have a significant impact on their child's performance. The mother's education and father's education variables are originally recorded in the student dataset in the `learningtower` package at distinct International Standard Classification of Education (ISCED) levels which are less than ISCED1 equivalent to ISCED 0, ISCED 1, ISCED 2, ISCED 3A and ISCED 3B, C, where:

- level 0 indicates pre-primary education or no education at all
- level 1 indicates primary education or the first stage of basic education
- level 2 indicates lower secondary education or the second stage of basic education, and
- level 3 indicates upper secondary education. ISCED level 3 have been further classified into three distinct levels, with ideally very little difference in their classification. This may also be found in the publication OECD Handbook for Internationally Comparative Education Statistics (Economic Cooperation & Development 1999) published by OECD.

To determine the impact of the parents' qualification we first create data frames that are categorized by the various countries and regions and grouped by the father's and mother's qualification. We next compute the weighted average of math scores while accounting for student survey weights. Furthermore, we re-factored the parents qualification variable based on the multiple levels of classification, dividing it into four unique levels of education, namely early childhood, primary, lower, and secondary education. Furthermore, we display the weighted math average versus qualification colored by the re factored qualifications levels for both the mother and father using the `geom_quasirandom` function wrapped within `ggplot2` (Wickham 2016), we further plot this with the help of `viridis` (Garnier et al. 2021) and `patchwork` (Pedersen 2020) packages in R.

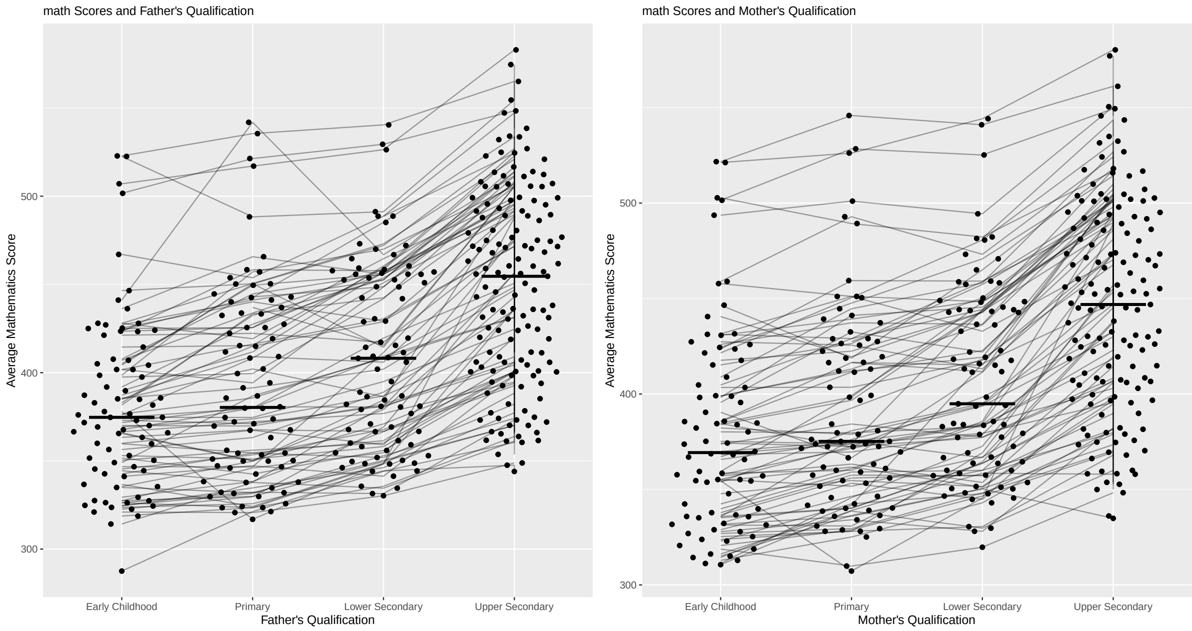


Figure 3: *The impact of parents' education on their children's academic progress is depicted in this graph. When the parents have greater levels of education, we see a considerable rise in scores and an increase in the median of scores for each category, as shown in the figure. In comparison to parents with lower levels of education qualifications. Parents who have tend to have upper secondary qualification or equivalent credentials their children are more likely to perform better in academics when compared with parent having lesser levels of qualifications.*

The Figure 3 depicts the impact of mothers' and fathers' qualifications on students academic performance. The Figure 3 allows us to deduce a very important and remarkable insight in which we see a constant increase in the students' academic performance when both mother and father qualifications shift towards higher levels of education. The bold horizontal black lines that we see in each category for mother's and father's qualification here represent median score for that qualification category across countries. As the parent attains higher qualifications, we notice an increasing trend in these medians for each category. Taking a closer look at the Figure 3, we can see that there is a considerable boost in scores when both the mother and father have upper secondary education. Furthermore, the `geom_quasirandom()` function in the `ggbeeswarm` (Clarke & Sherrill-Mix 2017) package makes this plot more accessible and understandable by providing a way to offset points inside categories to prevent overplotting. Thus, we can clearly see that both the mother's and father's qualifications has a significant influence on the student's academic performance, with the more educated the parent more likely to have their child academically performing better.

Students are becoming more active and adept learners as technologies like computers and internet mature and becoming more commonplace over the past twenty years. We will investigate if having a computer with internet access at the age of 15 has a positive or negative impact on student academic achievement. We will plot the average math results of the several nations that participated in the PISA experiment in 2022 to determine the effect of owning a computer and having access to the internet. We first create `data.frame` that is grouped by the nations and the frequency of whether the student possesses a computer or not, as well as a students' access to the internet or not. We will plot this result against the weighted average mathematical score to determine the influence of various of television and internet on the student academic performance using the several functions available in the `ggplot2`(Wickham 2016) package.

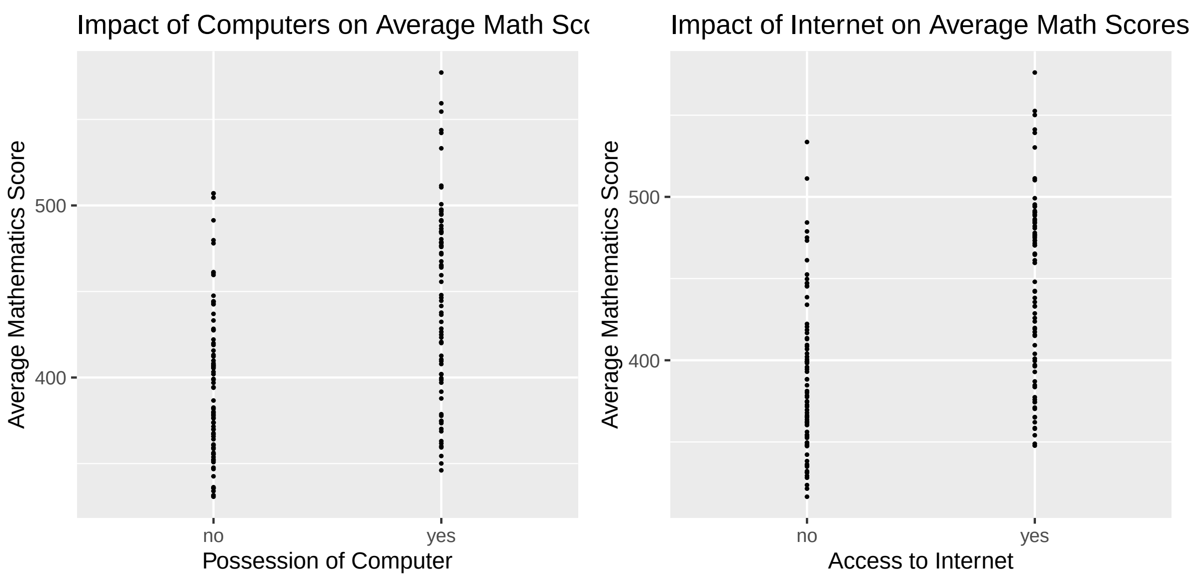


Figure 4: *Computers and the Internet are two of the most important inventions in the history of technology. In this figure, we observe the impact of owning a computer and having access to the internet on 15-year-old students all over the world. A remarkable finding from the plot is that all nations have higher scores in student performance when they own a computer and have access to the internet.*

In the Figure 4, we see that students who own a computer and have access to the internet consistently outperform students who do not own a computer or have access to the internet at all. No country has exempted from this finding. Thus, on average, a 15-year-old student's access to a computer and the internet is unquestionably has significant positive influence on their academic performance. While the increase in academic performance is expected, but the magnitude of this increase and the associated educational benefits may be used by policymakers to improve their own domestic access to these technologies.

Followed on previous discussion, computer has became an essential in learning experience. In this segment of the article, we investigate the influence of number of computers by countries/regions, as well as whether this technology has a significant impact on students' academic performance. The computer variables that are recorded in the student dataset is a factor variable that records whether or not the students participating in this study have a computer and, if they do, the quantity of computers per family is recorded via the PISA survey. Especially, in 2022 dataset, the survey also included the laptop variable. The computer and laptop variables are initially recorded has four levels: "No computer/laptop", "1 computer/laptop", "2 computers/laptops", or "3+ computer/laptops", respectively. Because we are interested in researching the impact of these computers and laptops on the students' scores, we visualized the confidence intervals for each of these levels in order to determine the uncertainty of the results at each level. We begin with initially creating a `data.frame` that is grouped by country and the number of computers and laptops per household for each country. Next we fit a linear model between the math average with computer and laptops in the 2022 PISA data and finally plot the impact for all countries sorted as per the slope with the help of the functions available in the `ggplot2` (Wickham 2016) package.

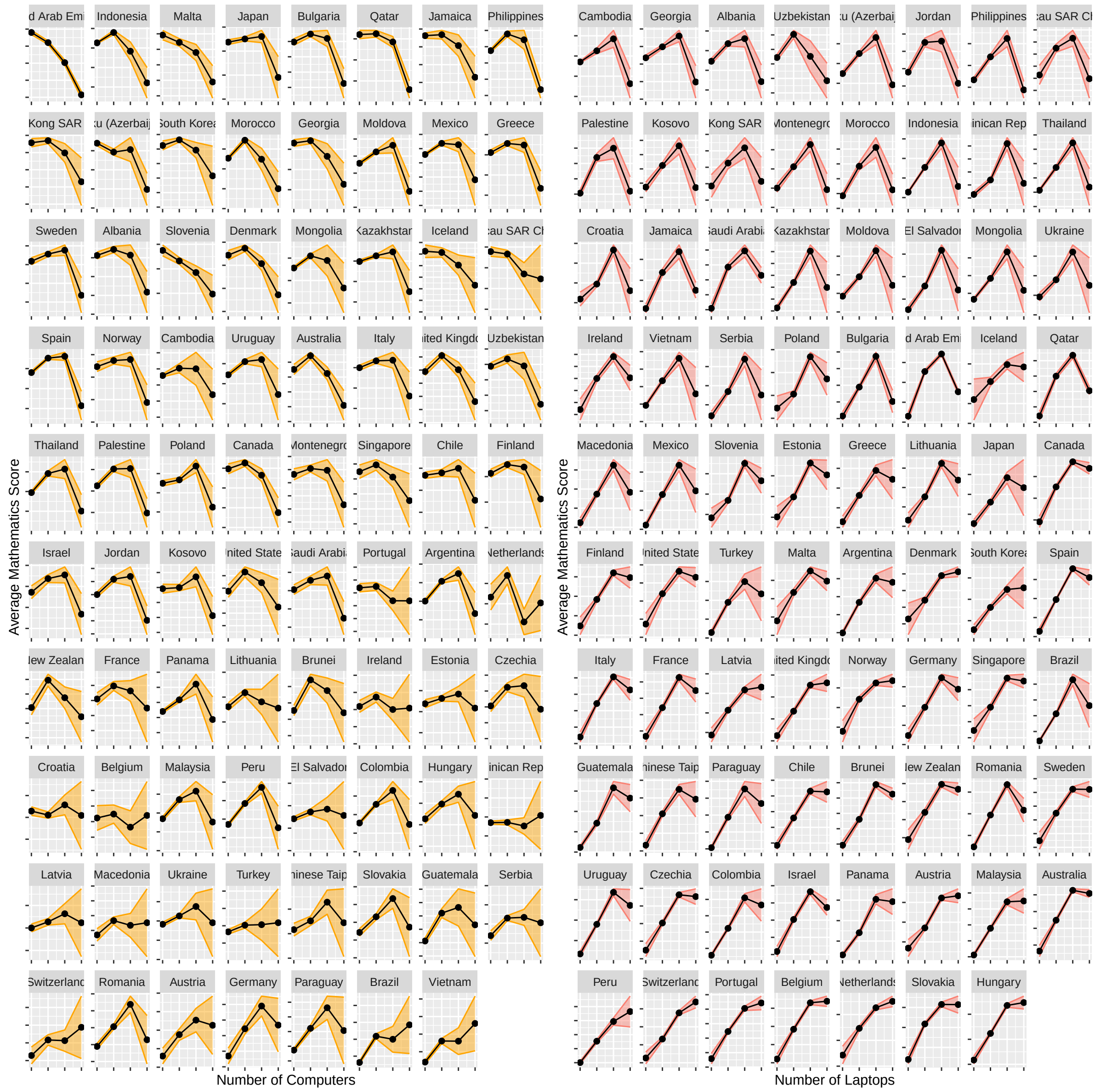


Figure 5: *Relationship between number of computers and laptops in a household and average math scores across countries. Number of computers/laptops ranges from 0 to 3 or more. The orange bands indicate 95 percent standard confidence intervals. The impact of computer/laptop on student performance is a contentious issue. It is interesting that the effect of computers and laptops are different across countries*

In the Figure 5, we can see highly striking patterns as well as a significant influence of television on students' academic performance. We have arranged the nations in the Figure 5 according to the slope of math average scores fitted against the different levels of computer/laptop described previously. United Arab Emirates and Indonesia have a lower influence of computer on student performance, whereas Brazil and Vietnam have a rising tendency and therefore a larger impact of computer on students' performance. Furthermore, the confidence interval plotted in the figure Figure 5 show that there is a lot of uncertainty in the level of scores when a household have more computers in the majority of the countries. On the other hand, Cambodia and Georgia have a lower influence of laptop on student performance, whereas Slovakia and Hungary have a rising tendency and therefore a larger impact of laptops on students' performance. Taking a closer look we observe that when the slope of laptop increases in countries, compared to the slope of computer, the confidence interval of such countries becomes narrower. Hence laptop could have more potential educational benefit compared to computer. It's quite interesting because the similar nature of computer and laptop, we would assume the effect of these two assets should be similar, yet the Figure 5 has not only shown a different result. Nevertheless, having multiple computers and laptops may turn out to be having negative influence on student's performance in most of the countries, excessive access could lead to distractions or excessive screen time, which can negatively impact performance.

9.1 Temporal Analysis

Pandemic effects

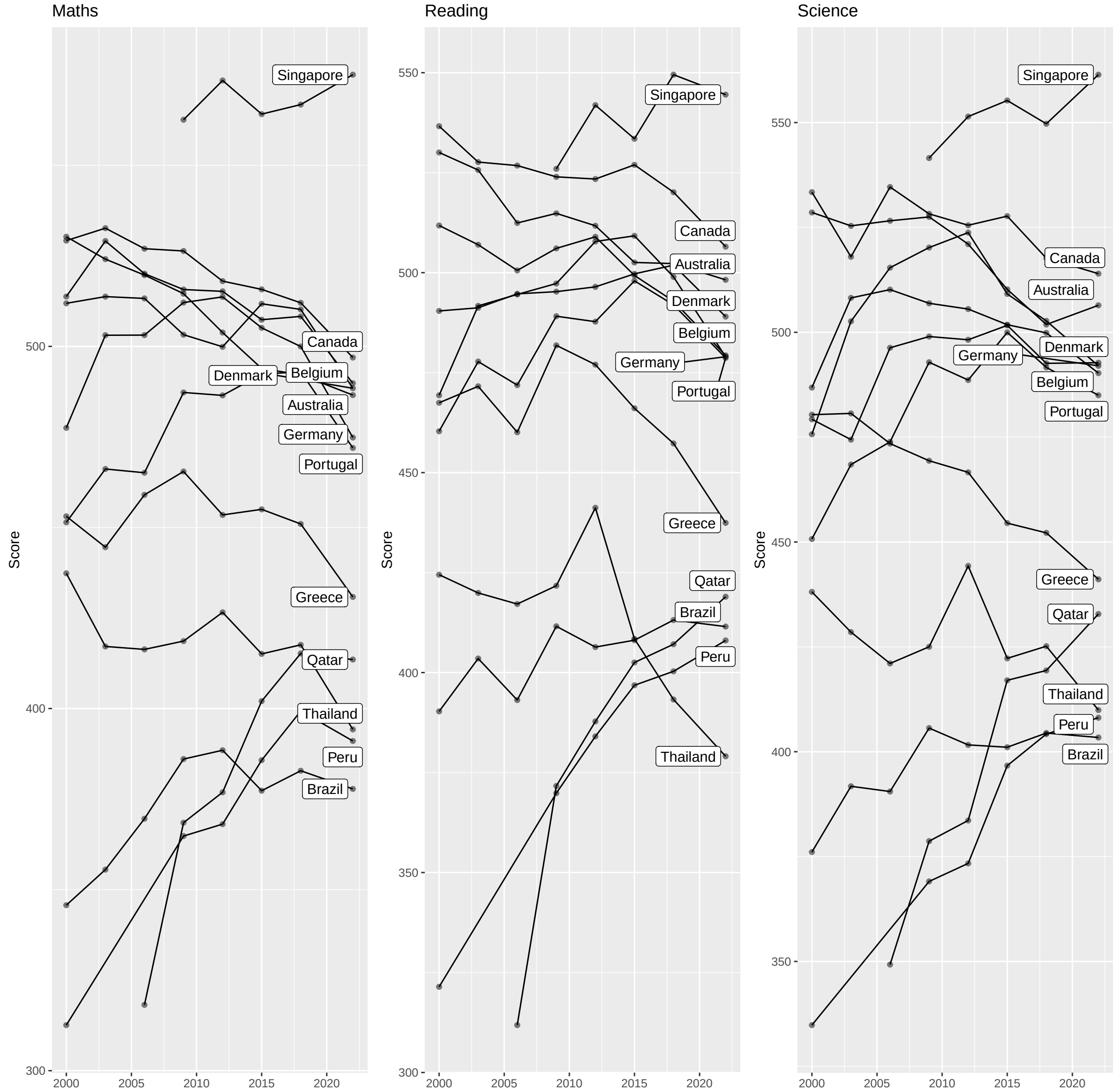
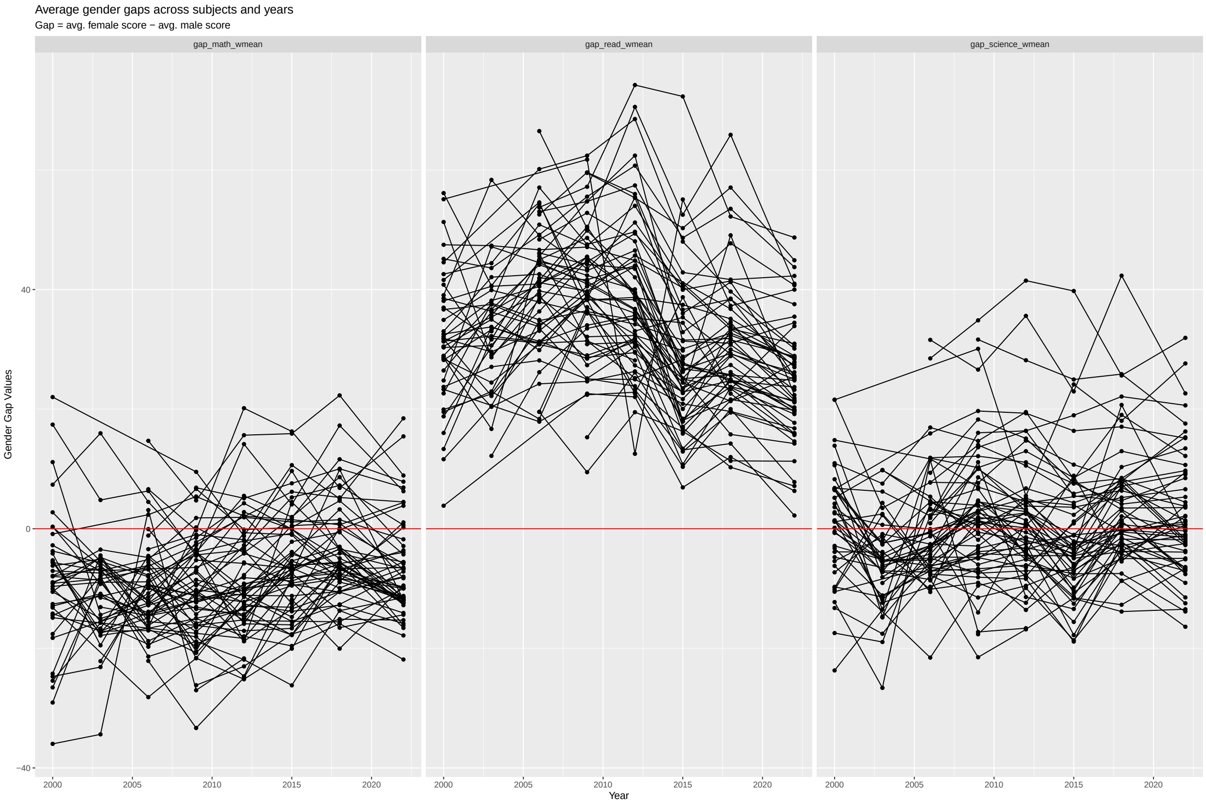
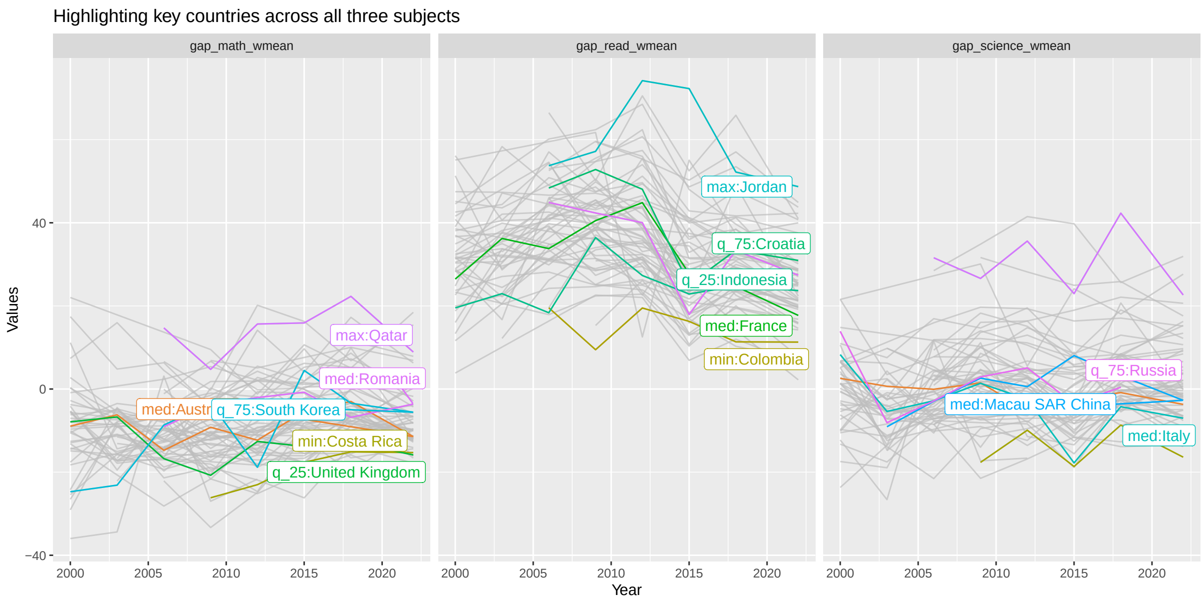


Figure 6: *Temporal patterns in math, reading, and science in a variety of countries. The highlighted countries in the chart help us infer Australia's performance in contrast to the other countries; we can see that Australia's scores have always been among the highest in the PISA survey throughout all years.*

Gender Gaps Across Subjects and Years



Highlighting Key Countries



10 Discussion

10.1 Limitations

- Size limitation on CRAN packages: The data size would be bigger if keep uploading the newest data, so further curation process of data should be considered, or explore alternative data compression for the datasets.

- Variables Consistency: The construction of questionnaire would be different every survey, as well as the coding mechanism of the original dataset, so curation process must be examined everytime to ensure the consistency of variables.

11 Conclusion

An important improvement is the addition of the 2022 PISA data to the learningtower R package, which provides current insights from student and school statistics. By providing a thorough grasp of student performance, school characteristics, and the factors impacting learning outcomes, this update facilitates a deeper comprehension of global educational dynamics. The program facilitates cross-country comparisons and rigorous longitudinal analysis by guaranteeing consistency across datasets from 2000 to 2022.

The learningtower package's improvements give educators, researchers, and policymakers useful tools for evaluating and enhancing educational institutions. The package promotes data-driven initiatives to address educational issues and advance fairness by providing a comprehensive strategy that integrates student and school data. Learningtower will remain a vital tool for expanding our knowledge of global educational trends and promoting significant learning gains as long as it is updated to include upcoming PISA statistics.

12 Reference

12.1 Git respository of the report

https://github.com/Shabarish161/Learningtower_Rpackage

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