The Impacts of Psychological Traits on Mathematics Grades in South Korea

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Abstract:

This study investigates the relationship between psychological traits and mathematics achievement among South Korean students, set against the backdrop of the country's rapid shift towards the Fourth Industrial Revolution and post-COVID-19. Utilising data from the 2022 Programme for International Student Assessment (PISA) dataset, this research employs both traditional statistical approaches and machine learning techniques to analyse the impact of psychological factors such as life satisfaction, confidence in mathematics, will to study mathematics, and students' feelings of safety on mathematics performance. The findings reveal a statistically significant relationship between some of these psychological traits and mathematics grades. However, the machine learning model's predictive accuracy was not significantly high, suggesting that a more comprehensive understanding of the various factors influencing academic success is necessary. These insights have implications for developing policies and programmes aimed at enhancing mathematics achievement and fostering a more inclusive learning environment for South Korean students.

Introduction

South Korea's industrial structure is rapidly transitioning towards focusing on the Fourth Industrial Revolution and cutting-edge technology. As a result of this transformation, among foundational education skills such as reading, mathematics, and science, mathematics has become the most significant subject (Park, 2023). Mathematics lies at the core of the Fourth Industrial Revolution, prompting scholars to conduct more research on how to enhance students' mathematical abilities in South Korea.

On the other hand, since the COVID-19 pandemic, the number of Korean adolescents who are suffering from depression has increased, now reaching more than 37,386. Compared to 2018, it increased by approximately 60% in 2022. According to the research from the Suicide Prevention Resource Center (2020), students' energy, concentration, independence, optimism, and education attainment can be changed based on their psychological conditions. In addition, negative mental conditions can adversely affect students.

According to Figure 1, following the COVID-19 pandemic, the average mathematics scores of OECD member countries declined from 489 points in 2018 to 472 points in 2022 (OECD, 2023). In the case of South Korea, while there was little change between 2018 and 2022, with scores of 526 and 527 points respectively, the situation remains stagnant in terms of mathematics performance improvement. After a drop from 554 points in 2012 to 524 points in 2014, South Korea's mathematics scores have remained relatively unchanged, showing little improvement since then.

In this context, a question arises regarding the relationship between students' psychological traits and their achievements in mathematics. Hence, this paper will focus on the psychological traits that have been recently highlighted due to their potential impacts on students' mathematics outcomes. Through quantitative analysis, students will be categorised into several groups based on their psychological conditions to solve research question 1: whether psychological traits have a statistically significant impact on mathematics scores. A statistical analysis of group comparisons will be employed to assess the differences. Additionally, this research will statistically examine the relationship between psychological states, considered as independent variables, and mathematics performance, treated as a dependent variable, using ordinary least squares. Last but not least, through machine learning techniques, this study will investigate research question 2: whether those psychological traits have a strong potential to precisely predict the mathematics performance of South Korean students.

Background

Industrial Structure and Trend in South Korea

In 2023, South Korea had $1.7 trillion in Gross domestic product (GDP) and this is 13th in the world (IMF, 2023). Korea's GDP consists of mainly services, industry, and agriculture, holding 58.3%, 39.3% and 2.2% (Central Intelligence Agency, 2023). The Republic of Korea is one of the countries where the manufacturing sector holds the highest position in the industry globally. Pivotal industries in South Korea include semiconductors, rechargeable batteries, electronic devices such as smartphones and home appliances, steel, shipbuilding, automobiles, petroleum refining, petrochemicals, and shipping (KIET, 2020).

Furthermore, a substantial portion of Korea's GDP, approximately 84%, is accounted for by the top 64 major companies, most of which operate within these aforementioned sectors. According to the Korean Ministry of Education (2020), there was a trend for university graduates who got jobs in major companies in 2019. Specifically, engineering majors accounted for 50.6% and natural sciences accounted for 11.3%. Therefore, the two departments surpassed the humanities and social sciences (total 30%) by double the rate. Therefore, it is obvious that engineering and natural science fields, which heavily rely on mathematics, play an important role in Korea's industries.

Moreover, due to the Fourth Industrial Revolution, the Korean government and companies are also attempting to develop and utilise cutting-edge technologies such as Artificial Intelligence, Big Data, Blockchain, and so on (Kim, 2021). As all these technologies are being developed with mathematics as their primary foundation, outstanding mathematical skills are becoming an essential prerequisite for future leaders.

Psychological Traits and Conditions

Depression, anxiety, and self-esteem are among the well-known psychological traits (World Health Organization, 2022). These traits, along with individuals' cognition, behaviour, and emotional self-regulation, are related to psychological conditions. A clinically significant disruption in these psychological traits can cause some mental disorders such as anxiety disorders, depression, disruptive behaviour, and a decrease in self-esteem (World Health Organization, 2022).

Recently, psychological status has been considered an essential factor in education. Fletcher (2009) suggests that adolescent depression might impact educational attainment, such as in mathematics. However, he noted the difficulty in making causal interpretations of research findings. Nonetheless, the results indicate a negative correlation between adverse psychological conditions and both years of schooling and educational achievement (Fletcher, 2009).

In line with the research of Fletcher in 2009, the research of Sabani and Saban (2022) also found that self-confidence, recognised as one of the major psychological traits, is crucial for academic achievement. This is because children with strong self-confidence are more likely to acquire new knowledge, confront challenges, and make independent decisions (Sabani and Saban, 2022).

Methodology

Data

To collect relevant reports and information, the University of Sussex Library and Google Scholar have been used. In addition, the Programme for International Student Assessment (PISA) 2022 dataset from OECD has opted to conduct a quantitative analysis. In this dataset, around 700,000 15-year-old students from 81 OECD partner and member countries are included. It is important to note that, due to the COVID-19 pandemic, the PISA 2022 dataset has some issues such as low survey response rates (OECD, 2023).

Among nearly 700,000 students' data, this study extracted only South Korean students' data. Moreover, it used some features, namely confidence in mathematics, life satisfaction, students' feeling of safety, will to study mathematics, loneliness, anxiety about mathematics and student resilience, which are part of psychological traits. Each variable was created by aggregating related questions and calculating the overall mean. Furthermore, several separate variables were created to group the attributes for conducting the T-test and F-test. As a result, the total number of obtained data points from the students in South Korea was 6,454. However, a significant number of missing values, 2,382 data points, were detected. Because of the absence of information about the data collector, it is statistically dangerous to substitute these missing data points into certain values. Therefore, the decision was made to eliminate all missing values to conduct a statistical analysis. On the other hand, this dataset does not contain any duplicated values. After processing missing values for smooth quantitative analysis, 4,072 data points were secured. Meanwhile, since the mathematics scores of Korean students consist of values that are all potentially real, outliers were not handled in the statistical analysis to ensure fair consideration of all mathematics grades. For more detail, appendix 1 describes the entire variables including scale configuration.

Statistical Approach

This research will employ a statistical group comparison analysis and ordinary least squares as statistical approaches through Stata and Python. First, this research defines a statistical group comparison analysis as statistical tests used to determine whether the difference in responses between groups is statistically significant. It consists of several methodologies. Among the methods, a t-test is applied to assess if a set or sets of scores originate from the same population (Coakes and Steed, 1999, p.61). The t-test comprises three different tests: the one-sample t-test,

independent samples t-test, and paired samples t-test. Among these, the independent samples t-test will be utilised in this essay, as it will compare various groups exhibiting different psychological traits. Additionally, an F-test is a statistical method employed to assess the equality of variances among two or more samples or to compare the ratio of variances between multiple samples. This statistical technique utilises the F-statistic, which is a random variable, to ascertain whether the data being examined adheres to an F-distribution assuming the true null hypothesis and appropriate assumptions regarding the error term (Berger, P. D., Maurer, R. E., and Celli, G. B., 2018). When the need arises to compare more than two different groups, employing an F-test is deemed an appropriate approach for statistical analysis.

Meanwhile, in terms of statistics, ordinary least squares (OLS) is a technique used in linear regression to estimate the unknown parameters of a linear model. It operates on the principle of minimising the sum of squared residuals, where residuals are the differences between observed and predicted outputs of the dependent feature based on the independent features (Chumney, Simpson and American Society of Health-System Pharmacists, 2006). Examining the regression coefficients and their associated p-values can determine which variables affect others, the degree of their impact, and ascertain whether this relationship is statistically significant or merely coincidental (Chumney, Simpson and American Society of Health-System Pharmacists, 2006). The relationship between mathematics grades and psychological traits will be identified through OLS.

Machine Learning

Machine Learning (ML) is a component of artificial intelligence that involves the capacity of a machine to mimic intelligent human behaviour (Brown, 2021).

ML can acquire knowledge from data and information autonomously, without relying on predefined equations or explicit instructions (Tondak, 2020). With the increasing accessibility of various datasets, the importance of ML has been underscored. Within ML, two methodologies, namely 'Supervised Learning' and 'Unsupervised Learning,' are recognised.

Supervised Learning utilises labelled training data samples from a dataset with predefined classifications or dependent values, whereas unsupervised learning operates on unlabeled training data samples (Sathya and Abraham, 2013). Regression is the most famous methodology to measure and identify the relationship between a dependent variable and independent variables believed to spell out it (Ramcharan, 2019). Several regression techniques can be opted for, including Linear Regression, Lasso Regression, Ridge Regression, and Decision Tree Regression, among others. In this study, linear regression, a supervised learning approach, will be employed to investigate whether psychological traits have a strong potential to predict the mathematics performance of South Korean students.

Empirical Finding

Descriptive Analysis

Before delving into the quantitative analysis, the statistics of each variable were examined. These statistics include the mean value, range of values, mode, variance, and standard deviation. Table 1 outlines these statistics for the seven independent variables as well as the dependent variable.

Ordinary Least Squares

To conduct OLS, multicollinearity between independent variables has been examined through the variance inflation factor (VIF). VIF compares how much a parameter's variance changes when it is included in a full model versus when it's in a model by itself. If a value of VIF is greater than 5, the variable has a high correlation with other variables (James et al., 2023).

According to Figure 2, all variables show small figures of VIF, indicating no significant multicollinearity among these independent variables. Therefore, all independent variables were included in the OLS analysis.

Based on the OLS results (Figure 3), the model's F-statistic is 343.59, with an R-squared value of 0.372 and a constant of 331.72. This explains that approximately 37.2% of the variation in the dependent variable can be explained by the independent features in the model. When the life satisfaction and students' feeling of safety increase by 1 unit, the mathematics grade of a student decreases by 2.65 and 9.45. Conversely, a 1-unit rise in confidence in mathematics and the will to study mathematics leads to a student's mathematics grade increasing by 65.78 and 27.59, respectively.

Meanwhile, the p-value of loneliness, anxiety about mathematics and student resilience are more than the significant level of the model, which is 0.05. Consequently, these psychological traits are not statistically significant in predicting the dependent variable. Therefore, they were excluded from the OLS model and further quantitative analysis.

Statistical Group Comparison Analysis

Through the OLS model, the four psychological traits, namely life satisfaction, students' feeling of safety, confidence in mathematics and the will to study mathematics, have been proven that these are statistically significant. Thus, t-test and f-test were implemented to assess whether a statistically significant difference exists after grouping the independent variables. Grouping was conducted in order to categorise the data points based on the value of each variable and Appendix 2 provides further details on the grouped variables.

The F-test and T-test assume a normal distribution of the dependent variable. However, the mathematics score variable discovered that it does not follow a Gaussian distribution, as indicated

by the normality tests in Appendix 3. In such cases, the data is often subjected to bootstrapping methodology, as it can help approximate a normal distribution through the central limit theorem. Bootstrapping is a statistical method for estimating statistics by resampling from the dataset. Consequently, bootstrapping has been chosen to perform both the T-test and F-test with 10,000 bootstrap samples.

For all variables, the null hypothesis and alternative hypothesis for the T-test are defined as follows:

$$H_0 : \mu_1 = \mu_2$$
$$H_1 : \mu_1 \neq \mu_2$$

where μ_1 represents the mean of the mathematics score in group 1 and μ_2 denotes the mean of the mathematics score in group 2.

To assess differences between groups, a two-tailed test was implemented with a significance level of 0.05. In bootstrap hypothesis testing, due to the central limit theorem, the distribution of bootstrap sample means tends to approach a Gaussian distribution as the sample size is expanded. Therefore, in bootstrap t-tests, it is common to use z-scores instead of t-statistics to interpret the outcome of the test.

First of all, according to Appendix 4, the result of the bootstrap T-test between the high-confidence and low-confidence groups, the z-score is -32.87 and the p-value is 0.0. Therefore, the null hypothesis has been rejected. In addition, when examining the high-will and low-will to study mathematics groups, the z-score between the two groups is -25.89, with a p-value of 0.0. Thus, the alternative hypothesis has been accepted. Lastly, comparing groups with high and low levels of students' feeling of safety using a T-test, the z-score between the two groups is 3.78, with a p-value of 0.0. Hence, the null hypothesis was not able to be accepted.

On the other hand, the null hypothesis and alternative hypothesis are stated as follows in F-test:

$$H_0 : \mu_1 = \mu_2 = \mu_3$$
$$H_1 : \exists i, j \; s.t. \; \mu_i \neq \mu_j$$

where μ_1 represents the mean of the mathematics score in group 1, μ_2 denotes the mean of the mathematics score in group 2 and μ_3 represents the mean of the mathematics score in group 3.

According to Figure 4, in the F-test results for group differences based on the life satisfaction variable, the F-statistic is 5.7199 and the p-value is 0.003. With a significance level of 0.05, the null hypothesis has been rejected, allowing for the acceptance of the alternative hypothesis. As a result, at least one mean value of the life satisfaction group is statistically different from other groups.

To sum up, based on the results of the T-test and F-test, the independent variables, confidence,

will to study mathematics, students' feeling of safety and life satisfaction, are statistically significant in determining the mathematics grade. This aligns with the ordinary least squares (OLS) regression analysis findings.

Machine Learning

The OLS and statistical group comparison analysis proved that the four psychological trait variables have a significant relationship with mathematics achievement among students in South Korea. Hence, linear regression, one of the machine learning methodologies, was chosen to examine whether these features can accurately predict Korean students' mathematics scores. In this study, Python was utilised to construct the machine learning algorithm.

The original dataset underwent feature scaling using the Standard Scaler, as shown in Equation 1, to normalise the range of independent features in order to use these variables for a linear regression model. Since the range of values in each variable is slightly different based on Table 1, feature scaling is recommended.

Subsequently, the dataset was randomly divided into a training set (80%) and a test set (20%), with a total of 3,257 data points for the training dataset and 815 data points for the test dataset. The linear regression model was then trained using the training set, yielding the following equation for the model, described in Equation 2.

Afterwards, the model was evaluated using the test dataset. The mean squared error (MSE), root mean squared error (RMSE), and mean absolute error (MAE) were utilised for the assessment. The equations for the 3 loss functions and the results are as follows in Table 2 and Figure 5, respectively:

This model yielded an MSE of 6,923.18, an RMSE of 83.21, and an MAE of 65.90 within a value range of 203.89 to 836.95. As shown in Figure 5, the model almost correctly predicts mathematics scores at indices 1, 5, 8, 10, and 14. Be that as it may, considering the high MSE, RMSE, and MAE, it can be concluded that this machine learning model is unable to precisely capture mathematics grades solely based on psychological traits from the PISA dataset.

Conclusion

In conclusion, this study reveals a statistically significant relationship between psychological traits and mathematics grades, as confirmed by both the OLS and statistical group comparison analysis. From the PISA dataset, this research extracted life satisfaction, loneliness, confidence in mathematics, anxiety about mathematics, will to study mathematics, feeling of safety, and resilience as independent variables. Among these, life satisfaction, confidence in mathematics, will to study mathematics, and feeling of safety emerged as significant contributors to mathematics attainment, addressing the first research question.

However, while these analyses provide valuable insights into the impact of psychological factors on academic performance, it is crucial to acknowledge the limitations of relying solely on psychological traits to predict mathematics attainment. The linear regression machine learning model's predictive accuracy failed in precisely estimating mathematics scores based on the psychological traits from the 2022 PISA dataset. This implies that other factors beyond psychological traits, such as social environment, educational quality, and teaching methodologies, may also play essential roles in shaping students' mathematics performance. As such, this study failed to prove the second research question.

Therefore, it is recommended to implement further quantitative analysis incorporating these additional factors to obtain a more comprehensive understanding of mathematical achievement. By considering a broader range of variables, future research can provide deeper insights into the complex interaction between various factors influencing academic success.

These research findings have potential effects on the development of policies, strategies, and programs aimed at enhancing mathematical achievement for Korean students. To address the multifaceted nature of academic success, policymakers and educators are required to customise better approaches and systems including psychological traits aspect to meet the varied needs of students. It will ultimately encourage a more inclusive learning environment and enhance the mathematics attainment of Korean students.

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Tables and Equations

Table 1. Statistics of Each Variable

Name	Mean	Range	Mode	Variance	Median	Standard Deviation
Life Satisfaction	6.38	0 ~ 10	7	5.85	7.00	2.42
Loneliness	3.43	1 ~ 4	4	0.50	4.00	0.70
Confidence in Mathematics	2.40	1 ~ 4		0.55	2.45	0.74
Anxiety about Mathematics	2.62	1 ~ 4	3	0.65	2.60	0.81
Will to Study Mathematics	3.22	1 ~ 4.91		0.49	3.25	0.70
Feeling of Safety	1.56	1 ~ 4	1	0.34	1.50	0.58
Resilience	3.04	1 ~ 5	3	1.22	3.00	1.10
Mathematics Score	531.78	203.89 ~ 836.95	-	10567.46	536.48	102.79

Table 2. Equations for Three Loss Functions

Loss Function	Equation
Mean Squared Error (MSE)	$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$ Where Y represents the values of the dependent variable, $\hat{Y}$ denotes the predicted values of the dependent variable
Root Mean Squared Error (RMSE)	$RMSE = \sqrt{MSE}$
Mean Absolute Error (MAE)	$MAE = \frac{1}{n}\sum_{i=1}^{n}\lvert y_i - \hat{y}_i\rvert$ Where y represents the values of the dependent variable, $\hat{y}$ denotes the predicted values of the dependent variable

Equation 1. Standard Scaler

$$\boldsymbol{Standardisation} = \boldsymbol{x}' = \frac{\boldsymbol{x} - \bar{\boldsymbol{x}}}{\boldsymbol{\sigma}}$$

Where x represents the values of the variable to be standardised,
σ denotes the standard deviation of x and $\bar{x}$ means the mean of the variable x

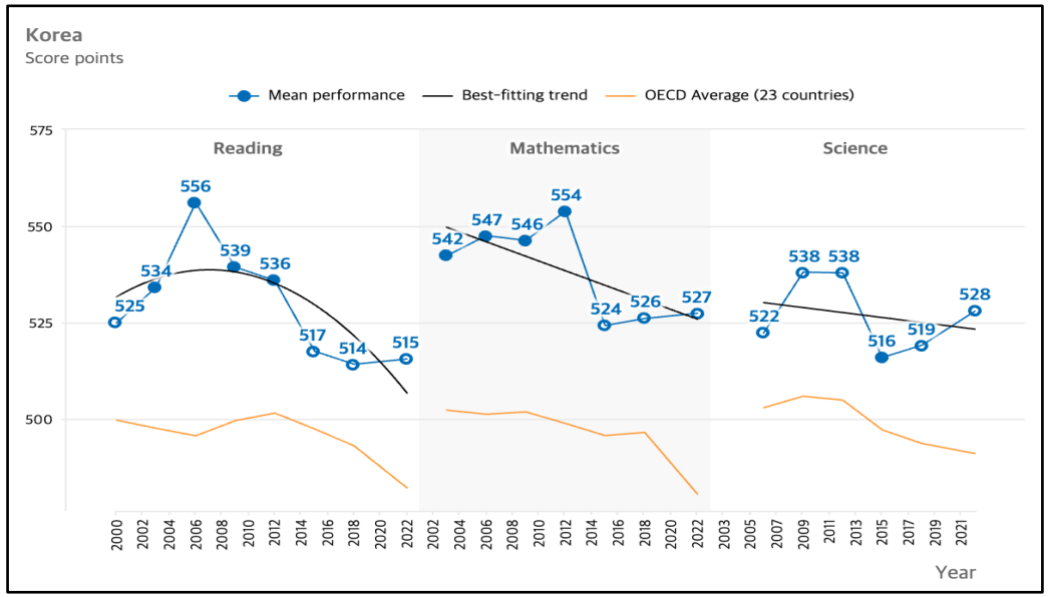
Equation 2. Linear Regression Model

$$\boldsymbol{y} = [-0.08059704 \quad 0.45665207 \quad 0.18943694 \quad -0.05754228] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} - 0.0027187492$$

Where x_1 represents life satisfaction, x_2 denotes confidence in mathematics, x_3 represents the will to study mathematics, and x_4 denotes students' feeling of safety.

Figures

Figure 1. Performance trends in mathematics, science and reading in South Korea



Source: https://oecdch.art/a40de1dbaf/C995

Figure 2. Result of VIF

Variable	VIF	1/VIF
confidence~h	1.89	0.528032
will_math	1.75	0.570948
life_satis~n	1.25	0.796837
anxiety_math	1.25	0.801853
lonely	1.18	0.844854
resilience	1.15	0.866230
feel_safe	1.15	0.872785
Mean VIF	1.38	

Figure 3. Result of OLS

Source	SS	df	MS		
Model	15994221.2	7	2284888.75	Number of obs	4,072
Residual	27025912.5	4,064	6650.0769	F(7, 4064)	343.59
Total	43020133.8	4,071	10567.461	Prob > F	0.0000
				R-squared	0.3718
				Adj R-squared	0.3707
				Root MSE	81.548

mscore	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
life_satisfaction	-2.649974	.5917757	-4.48	0.000	-3.810179	-1.48977
lonely	-2.046628	1.975171	-1.04	0.300	-5.919045	1.82579
confidence_math	65.78466	2.374561	27.70	0.000	61.12922	70.4401
anxiety_math	-.3363721	1.763935	-0.19	0.849	-3.794651	3.121907
will_math	27.5928	2.417793	11.41	0.000	22.8526	32.333
feel_safe	-9.447557	2.347646	-4.02	0.000	-14.05023	-4.844884
resilience	-2.384902	1.242716	-1.92	0.055	-4.821306	.0515011
_cons	331.7216	10.75146	30.85	0.000	310.6429	352.8004

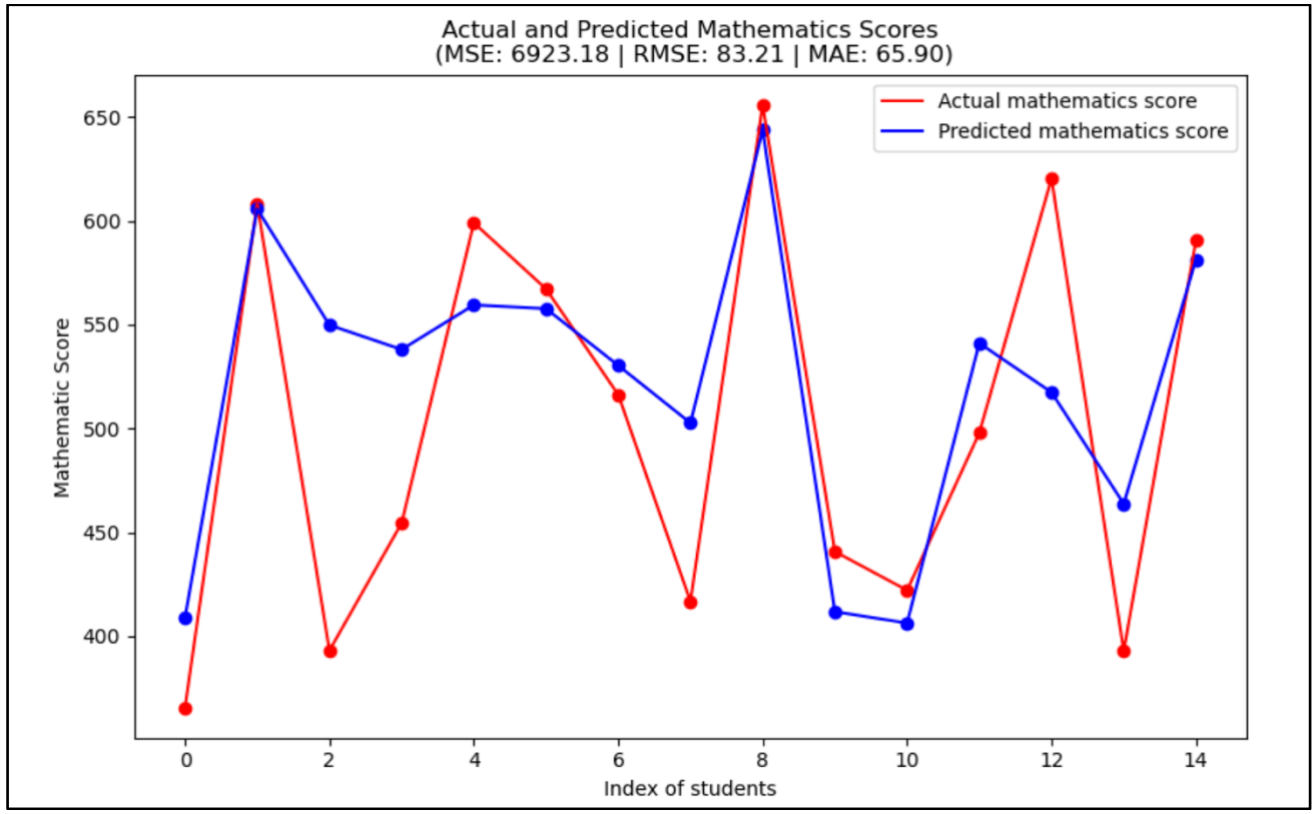
Figure 4. Result of F-test

```
                sum_sq      df         F    PR(>F)
group     1.206103e+05     2.0  5.719918  0.003306
Residual  4.289952e+07  4069.0       NaN       NaN

Mean value: 519.9409 vs 531.0384 vs 537.1833

F-statistic: 5.7199
p-value: 0.0033
Variable : life_satisfaction_group | There is a significant statistical difference
between mscore and each life_satisfaction_group
```

Figure 5. Result of Linear Regression Model (Machine Learning)



Appendices

Appendix 1. Detail of Variables (PISA 2022)

Variable	Question	Sub-Question	Scale Configuration	Code
Confidence in Mathematics	To what extent do you agree or disagree with the following statements?	Mathematics is easy for me	1-4	ST268Q04JA
	How confident do you feel about having to do the following mathematics tasks?	Working out from a train timetable how long it would take to get from one place to another	1-4	ST290Q01WA
		Calculating how much more expensive a computer would be after adding tax	1-4	ST290Q02WA
		Calculating how many square metres of tiles you need to cover a floor	1-4	ST290Q03WA
		Understanding scientific tables presented in an article	1-4	ST290Q04WA
		Solving an equation like $6x^2+5=29$	1-4	ST290Q05WA
		Finding the actual distance between two places on a map with a 1:10,000 scale	1-4	ST290Q06WA
		Solving an equation like $2(x+3) = (x+3)(x-3)$	1-4	ST290Q07WA
		Calculating the power consumption of an electronic appliance per week	1-4	ST290Q08WA
		Solving an equation like $3x+5=17$	1-4	ST290Q09WA
		Extracting mathematical information from diagrams, graphs, or simulations	1-4	ST291Q01JA
		Interpreting mathematical solutions in the context of a real-life challenge	1-4	ST291Q02JA
		Using the concept of statistical variation to make a decision	1-4	ST291Q03JA
		Identifying mathematical aspects of a real-world problem	1-4	ST291Q04JA
		Identifying constraints and assumptions behind mathematical modelling	1-4	ST291Q05JA
		Representing a situation mathematically using variables, symbols, or diagrams	1-4	ST291Q06JA
		Evaluating the significance of observed patterns in data	1-4	ST291Q07JA
		Coding/programming computers	1-4	ST291Q08JA
		Working with computer mathematics systems (ex: spreadsheets, programming software, graphing calculators)	1-4	ST291Q09JA
		Calculating the properties of an irregularly shaped object	1-4	ST291Q10JA

Variable	Question	Sub-Question	Scale Configuration	Code
Life Satisfaction	Overall, how satisfied are you with your life as a whole these days?		0-10	ST016Q01NA
Feeling of Safety	To what extent do you agree or disagree with the following statements?	I feel safe on my way to school	1-4	ST265Q01JA
		I feel safe on my way home from school	1-4	ST265Q02JA
		I feel safe in my classrooms at school	1-4	ST265Q03JA
		I feel safe at other places at school (e.g. hallway, cafeteria, restroom)	1-4	ST265Q04JA
Will to Study Mathematics	To what extent do you agree or disagree with the following statements?	I keep working on a task until it is finished	1-5	ST307Q01JA
		I apply additional effort when work becomes challenging	1-5	ST307Q02JA
		I finish tasks that I started even when they become boring	1-5	ST307Q03JA
		I am more persistent than most people I know	1-5	ST307Q05JA
		I complete tasks even when they become more difficult than I thoug ht	1-5	ST307Q08JA
		I finish what I start	1-5	ST307Q09JA
	To what extent do you agree or disagree with the following statements?	I love learning new things in school.	1-5	ST301Q05JA
	In a typical school week, approximately how much time do you spend on homework in the following subjects?	Mathematics homework	1-6	ST296Q01JA
	To what extent do you agree or disagree with the following statements?	Mathematics is one of my favourite subjects	1-4	ST268Q01JA
		I want to do well in my mathematics class	1-4	ST268Q07JA
	This school year, how often did you do each of the following?	I actively participated in group discussions during mathematics class	1-5	ST293Q01JA
		I paid attention when my mathematics teacher was speaking	1-5	ST293Q02JA
		I put effort into my assignments for mathematics class	1-5	ST293Q03JA
		I made time to learn the material for mathematics class	1-5	ST293Q05JA
		I asked questions when I did not understand the mathematics mater ial that was being taught	1-5	ST293Q06JA
		I started my work on mathematics assignments right away	1-5	ST293Q09JA

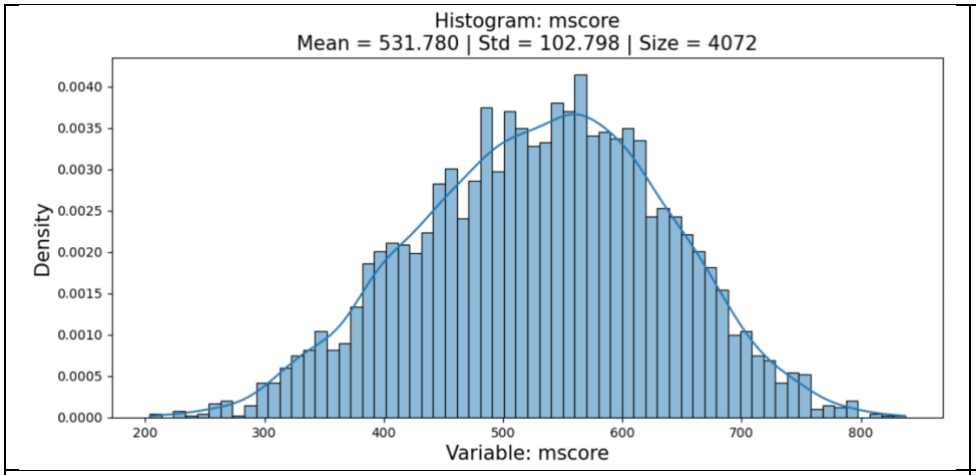
Variable	Question	Sub-Question	Scale Configuration	Code
Loneliness	Thinking about your school: to what extent do you agree with the following statements?	I feel lonely at school	1-4	ST034Q06TA
Anxiety about Mathematics	To what extent do you agree or disagree with the following statements?	I often worry that it will be difficult for me in mathematics classes	1-4	ST292Q01JA
		I get very tense when I have to do mathematics homework	1-4	ST292Q02JA
		I get very nervous doing mathematics problems	1-4	ST292Q03JA
		I feel helpless when doing a mathematics problem	1-4	ST292Q04JA
		I worry that I will get poor marks in mathematics	1-4	ST292Q05JA
		I feel anxious about failing in mathematics	1-4	ST292Q06JA
Resilience	To what extent do you agree or disagree with the following statements?	I can recover quickly after something bad has happened	1-5	ST345Q08JA
		I handle stress well	1-5	ST345Q09JA

Appendix 2. Detail of Grouped Variables

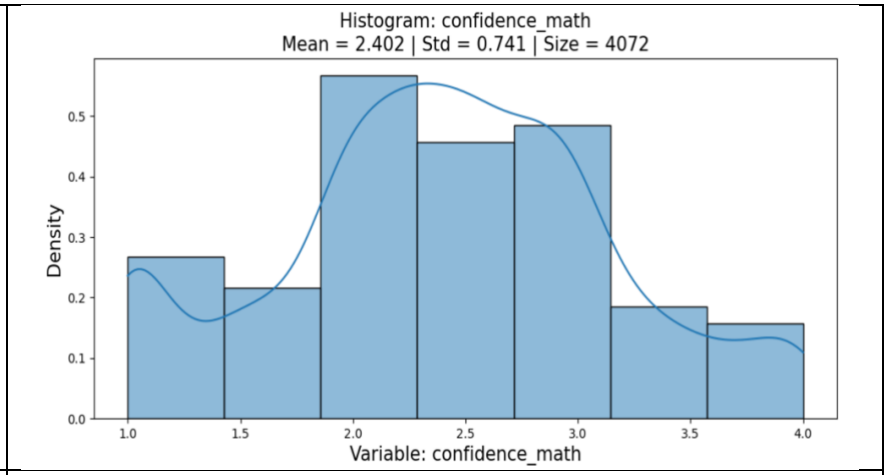
Variable	Value	Standard	Meaning
(Grouped) Confidence in Mathematics	0	0 ≤ Confidence in Mathematics ≤ 2.5	Low Confidence
	1	2.5 < Confidence in Mathematics	High Confidence
(Grouped) Will to Study Mathematics	0	0 ≤ Will to Study Mathematics ≤ 3	High Will
	1	3 < Will to Study Mathematics	Low Will
(Grouped) Loneliness	0	0 ≤ Loneliness < 3	Do Not Feel Lonely
	1	3 ≤ Loneliness	Feel Lonely
(Grouped) Feeling of Safety	0	0 ≤ Feeling of Safety ≤ 2.5	Feel Safe
	1	2.5 < Feeling of Safety	Do Not Feel Safe
(Grouped) Resilience	0	0 ≤ Resilience ≤ 2.5	Low Resilience
	1	2.5 < Resilience	High Resilience
(Grouped) Anxiety about Mathematics	0	2.5 < Anxiety about Mathematics	High Anxiety
	1	0 ≤ Anxiety about Mathematics ≤ 2.5	Low Anxiety
(Grouped) Life Satisfaction	0	0 ≤ Life Satisfaction < 4	Low Life Satisfaction
	1	4 ≤ Life Satisfaction < 8	Medium Life Satisfaction
	2	8 ≤ Life Satisfaction	High Life Satisfaction

Appendix 3. Data Visualisation (Histogram, Count Plot, ECDF Plot)

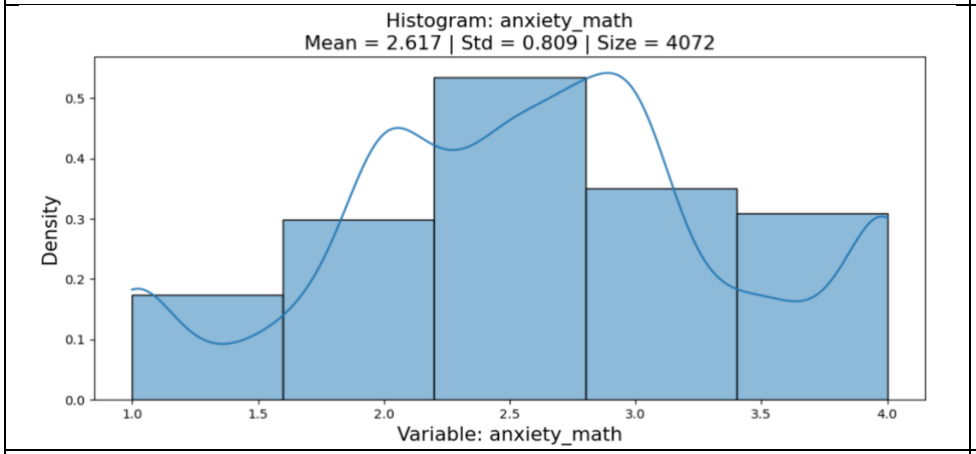
- Histogram



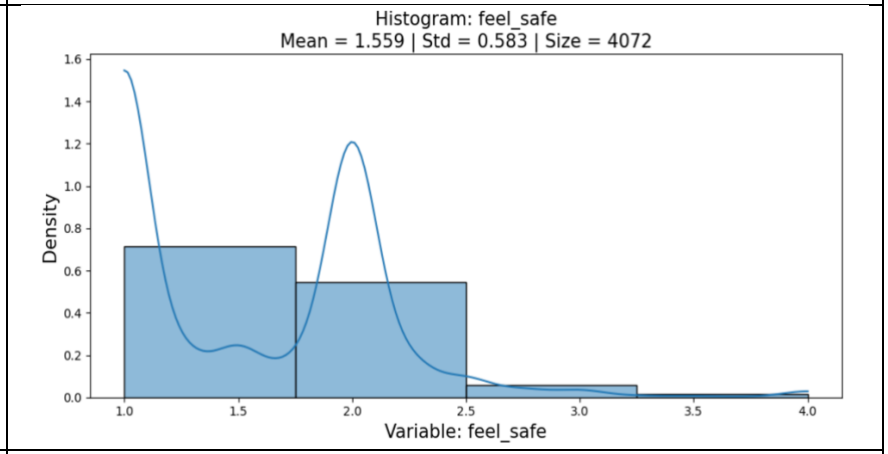
Mathematics Scores



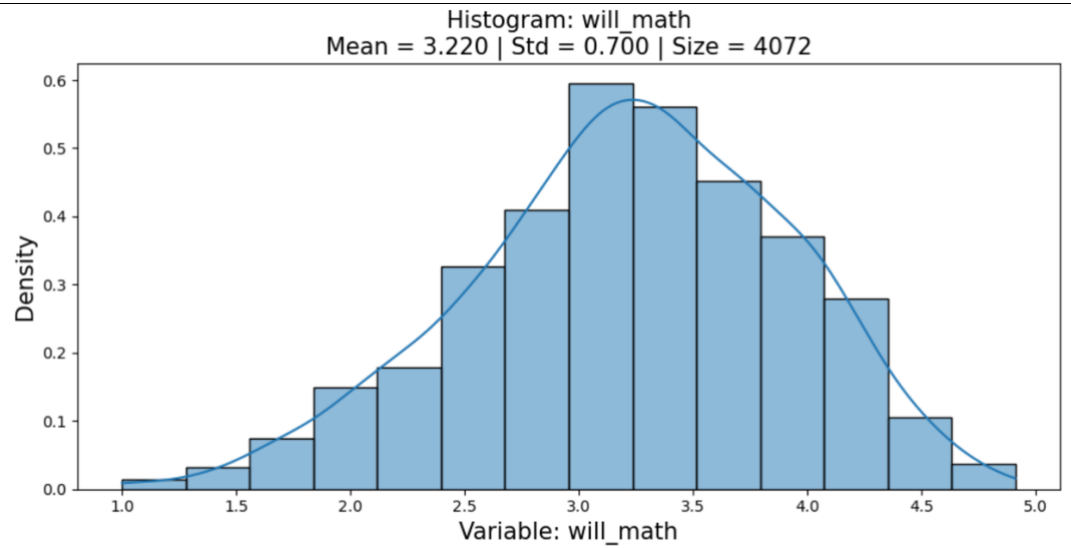
Confidence in Mathematics



Anxiety about Mathematics

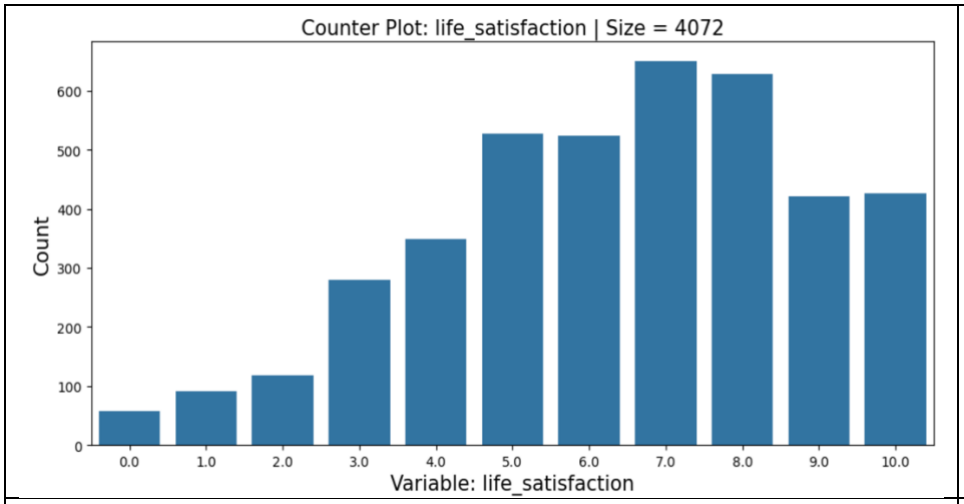


Feeling of Safety

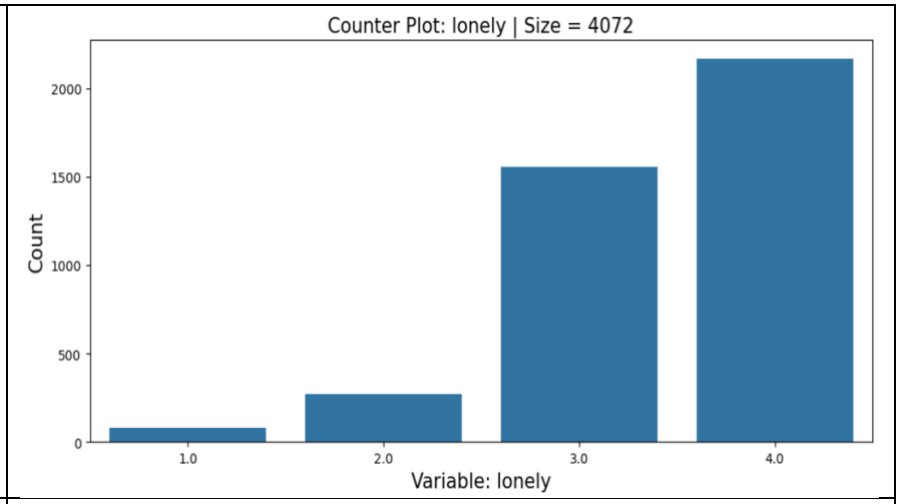


Will to Study Mathematics

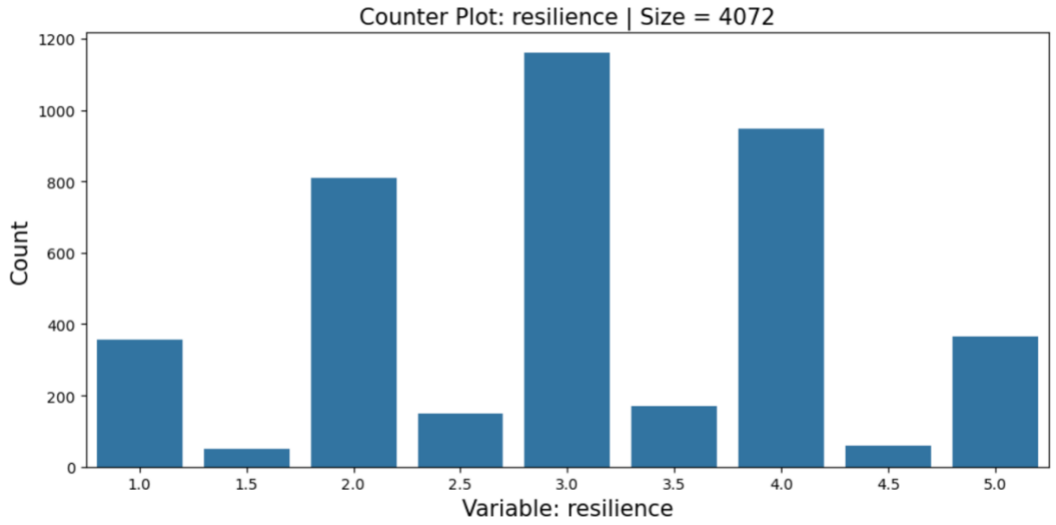
- Count Plot



Life Satisfaction

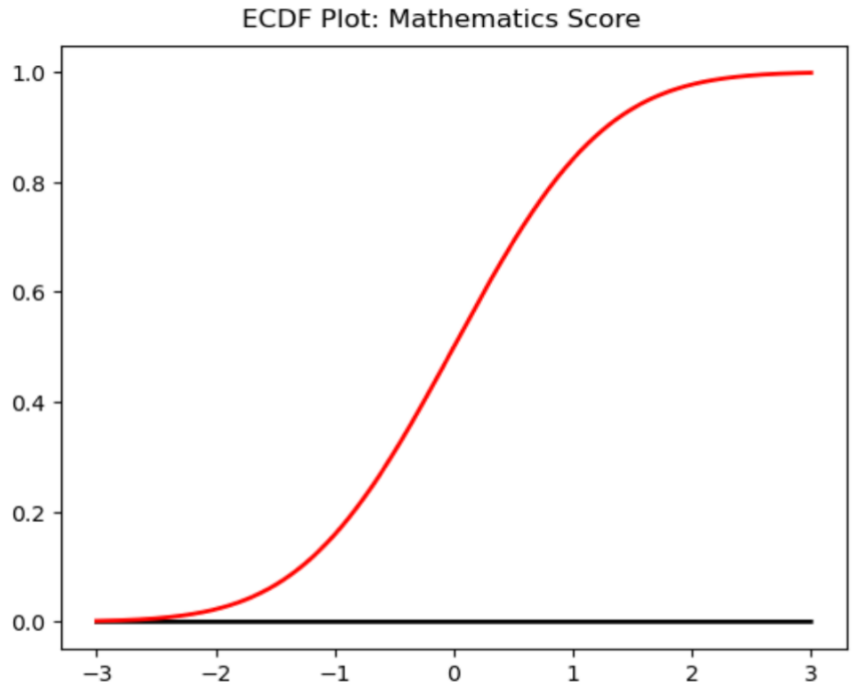


Loneliness



Resilience

- ECDF Plot (with Normality Tests)



Normality Test1 (D'Agostino-Pearson) P-value : 0.00000000 (Significance Level: 0.01)
Normality Test2 (Lilliefors) P-value : 0.00100000 (Significance Level: 0.01)

(1) D'Agostino Pearson Test

- Null Hypothesis: This variable follows a Gaussian Distribution
- Alternative Hypothesis: This variable does not follow a Gaussian Distribution
- P-value: 0.0000
- Significance Level: 0.01
- Result: Reject the null hypothesis

(2) Lilliefors Test

- Null Hypothesis: This variable follows a Gaussian Distribution
- Alternative Hypothesis: This variable does not follow a Gaussian Distribution
- P-value: 0.001
- Significance Level: 0.01
- Result: Reject the null hypothesis

Mathematics Scores

Appendix 4. Result of T-test

- Confidence in Mathematics

Result of T-test (Without Bootstrap)

```
. ttest mscore, by(confidence_math_group)

Two-sample t test with equal variances

   Group |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
       0 |   2,245    485.9005    1.915309    90.75009    482.1445    489.6564
       1 |   1,827    588.1574     2.04905    87.58339    584.1386    592.1761
---------+--------------------------------------------------------------------
Combined |   4,072    531.7805    1.610948    102.7982    528.6221    534.9388
---------+--------------------------------------------------------------------
    diff |           -102.2569    2.815063               -107.776   -96.73783
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t = -36.3249
H0: diff = 0                     Degrees of freedom =     4070

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Result of T-test (With Bootstrap)

```
Bootstrap results                                     Number of obs =  4,072
                                                      Replications  = 10,000

      Command: ttest mscore, by(confidence_math_group)
    diff_mean: r(t)

-------------------------------------------------------------------------------
             |   Observed   Bootstrap                         Normal-based
             | coefficient  std. err.      z    P>|z|     [95% conf. interval]
-------------+-----------------------------------------------------------------
   diff_mean |    -36.3249   1.105107   -32.87   0.000    -38.49087   -34.15894
-------------------------------------------------------------------------------
```

- Will to Study Mathematics

Result of T-test (Without Bootstrap)

```
. ttest mscore, by(will_math_group)

Two-sample t test with equal variances

   Group |     Obs        Mean    Std. err.   Std. dev.   [95% conf. interval]
---------+--------------------------------------------------------------------
       0 |   1,564    480.0641    2.422948    95.8214    475.3115    484.8167
       1 |   2,508     564.031    1.865338     93.416    560.3733    567.6888
---------+--------------------------------------------------------------------
Combined |   4,072    531.7805    1.610948   102.7982    528.6221    534.9388
---------+--------------------------------------------------------------------
    diff |           -83.96695    3.039834               -89.92669   -78.00721
------------------------------------------------------------------------------
    diff = mean(0) - mean(1)                                      t = -27.6222
H0: diff = 0                                     Degrees of freedom =     4070

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

Result of T-test (With Bootstrap)

```
Bootstrap results                                     Number of obs =  4,072
                                                      Replications  = 10,000

      Command: ttest mscore, by(will_math_group)
    diff_mean: r(t)

-------------------------------------------------------------------------------
             |   Observed   Bootstrap                         Normal-based
             | coefficient  std. err.      z    P>|z|     [95% conf. interval]
-------------+-----------------------------------------------------------------
   diff_mean |  -27.62222   1.066993   -25.89   0.000    -29.71349   -25.53095
-------------------------------------------------------------------------------
```

- Feeling of Safety

Result of T-test (Without Bootstrap)

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf.	interval]
0	3,945	532.9744	1.628897	102.3098	529.7809	536.168
1	127	494.6918	9.863544	111.1565	475.1721	514.2114
Combined	4,072	531.7805	1.610948	102.7982	528.6221	534.9388
diff		38.28268	9.24922		20.14915	56.41621

diff = mean(0) - mean(1) t = 4.1390

H0: diff = 0 Degrees of freedom = 4070

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0

Pr(T < t) = 1.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 0.0000

Result of T-test (With Bootstrap)

Bootstrap results Number of obs = 4,072

Replications = 10,000

Command: ttest mscore, by(feel_safe_group)

diff_mean: r(t)

	Observed coefficient	Bootstrap std. err.	z	P>|z|	Normal-based [95% conf.	interval]
diff_mean	4.139017	1.095099	3.78	0.000	1.992663	6.285372