

Research on the Effects of Learning environment on Students' Academic Performance

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ABSTRACT

This paper evaluated whether the learning environment can affect students' performance in reading, mathematics and science. Using the data from PISA, the paper analyzed the relationship between having classic literature, books of poetry, and works of art and students' scores in reading, mathematics and science using Hotelling's T-squared test and three-way between-subjects MANOVA.

CCS Concepts

• General and reference→Cross-computing tools and techniques→Measurement

General and reference→Cross-computing tools and techniques→Evaluation

Mathematics of computing→Probability and statistics→Statistical paradigms→Regression analysis

Applied computing→Operations research→Decision analysis

Keywords

Learning environment; Learning methods; Academic performance; Hotelling's t-squared test; MANOVA; multivariate model.

1. INTRODUCTION

1.1 PISA

The Programme of International Student Assessment (PISA) takes international surveys in OECD member countries and a group of partner countries every three years since 2000 to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students (<http://www.oecd.org>). The questionnaires of surveys collected information about the students' backgrounds, schools and learning experiences and about the broader school system and learning environment.

This paper focuses on the influence of learning environment on students' academic achievement and tries to evaluate their ability in reading, mathematics and science.

1.2 Research Purpose

With the information provided from PISA, many researches as been conducted to evaluate backgrounds, performance in schools, teaching systems, and other aspects, and there are relatively fewer researches about student's learning environment which relates closely with students' learning. The places together with the

furnishing and accessories in it not only reviews students' learning habits and interests, but also can be arranged to guide their behaviors and understanding of the real world in purpose. Thus, to figure out if educator, schools, parents and students' themselves can arrange the learning environment to improve students' skills and knowledge and the effectiveness of doing so, it is important to evaluate the relationship between learning environment and students' academic performance. Therefore, the following paper will then evaluate if students' performance in reading, mathematics and science are affected by the learning environment, especially the accessories in room.

2. DATA

The data used in this research come from the "GGally" package in R, which named "australia_PISA2012." It contains the information from survey results from Australia in PISA 2012, which was the programme's fifth survey. There were about 14,500 students from 800 schools participated in this survey, and this data provides records of 8247 observation (Thomson, 2013). After omitting the missing data, the sample size of this research is 7790. The dependent variables are scores in mathematics, reading and science, and PISA provided five plausible values for each subject, which are random values generated from the distribution of each student's reported score. Thus, the means of five plausible values in three subjects are used in analysis. The independent variables in the data were results of the question "Which of the following are in your home?" and there are 12 variables including "a desk to study at, a room of your own, a quiet place to study, a computer you can use for school work, educational software, a link to the internet, classic literature (e.g. <Shakespeare>), books of poetry, works of art (e.g. paintings), books to help with your school work <Technical reference books>, a dictionary, a dishwasher" and answer of yes was recorded as 1 while no was recorded as 0. Among all these variables, only "classic literature", "books of poetry", and "works of art" are used as predictors. Because while evaluating if there are effects from dependent variables, we want the sample sizes of whether student has one particular item in the home or not to be close, and from table 1, Sample variable and dependent variable analysis table, classic literature, books of poetry, and works of art variables have mean relatively closer to 0.5.

3. Methods

The analysis methods use here are Hotelling's T-squared test and three-way between-subjects MANOVA. While independent means t-test compares the means between two groups in univariate model, Hotelling's t-squared test compares the centroids between two groups in multivariate model by evaluating the squared distance (weighted Mahalanobis distance) between

centroids. The between-subjects MANOVA using Pillai's trace

tests the main and interaction effects by evaluating the generalized nonredundant variance between groups.

Table 1. Sample variable and dependent variable analysis table

	n	mean	sd	median	min	max	range	skew	kurtosis
desk	7790	0.91	0.29	1	0	1	1	-2.76	5.63
room	7790	0.93	0.26	1	0	1	1	-3.3	8.89
study	7790	0.88	0.32	1	0	1	1	-2.36	3.57
computer	7790	0.97	0.16	1	0	1	1	-5.75	31.08
software	7790	0.77	0.42	1	0	1	1	-1.26	-0.41
internet	7790	0.96	0.19	1	0	1	1	-4.85	21.53
literature	7790	0.38	0.49	0	0	1	1	0.49	-1.76
poetry	7790	0.35	0.48	0	0	1	1	0.63	-1.61
art	7790	0.74	0.44	1	0	1	1	-1.09	-0.81
textbook	7790	0.78	0.41	1	0	1	1	-1.34	-0.19
dictionary	7790	0.95	0.21	1	0	1	1	-4.25	16.1
dishwasher	7790	0.7	0.46	1	0	1	1	-0.89	-1.21
AveMath	7790	505.42	92.21	504.76	145.05	819.53	674.48	0.03	-0.15
AveRead	7790	514.42	91.15	516.65	65.34	769.93	704.59	-0.25	0.08
AveScie	7790	523.15	95.02	526.38	63.26	822.21	758.95	-0.12	-0.12

3.1 Assumptions

Before running Hotelling's t-squared test and between-subject MANOVA, assumptions including random sample, outliers, multivariate normality, linearity, and homogeneity of covariance matrices. Since the survey is not for random sample as both the schools and students from a school that participated were not randomly selected, and also these is the data from Australia, there is a limitation when generalizing the research result.

3.1.1 Linearity

In Figure 1, the scatterplots of overall and between groups models show that the relationship between dependent variables are linear, strong and positive. Thus, the linearity has been meet of using the MANOVA.

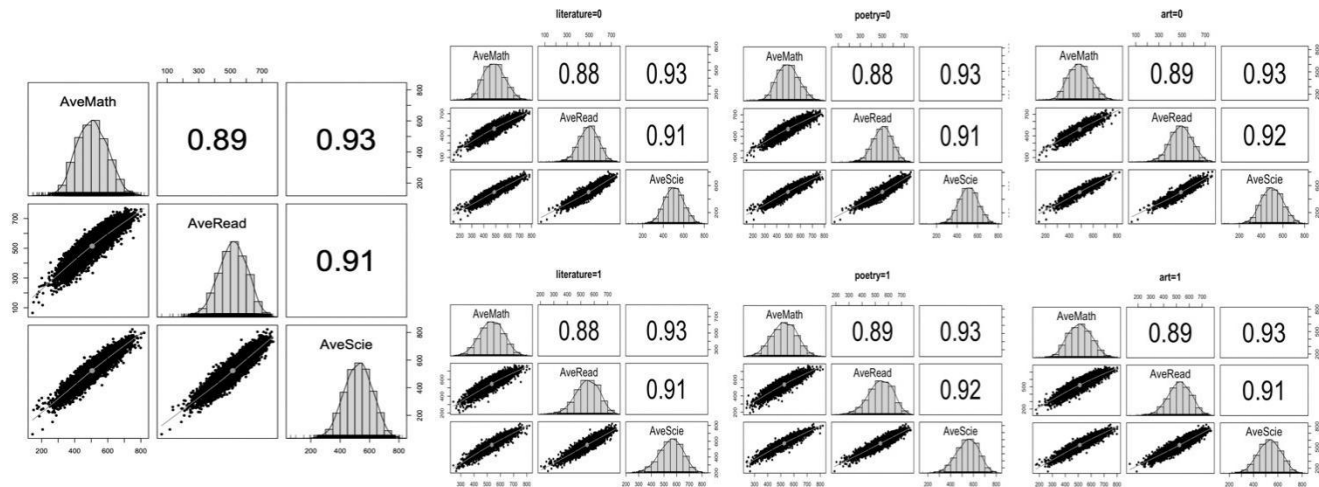


Figure 1. the scatterplots of overall and between groups models ©Rao Xiong

3.1.2 Multivariate Normality

Univariate skew and kurtosis are shown in the table 2, and they look good to have skews and kurtosis close to 0. For the multivariate skew and kurtosis, Mardia's test is used with false-positive rate of 0.001. The result from R shows that except for Mardia's kurtosis of group that art equals 0, the other statistics are

all significant with p-value less than 0.001. Also, QQ plots show patterns of curves. Thus, all six models (three predictors with group of two) are not multivariate normal, and this will probably inflate the Type 1 error in later analysis.

3.1.3 Homogeneity of Covariance Matrices

Box's M test is used to analyze whether the group covariance matrices are equal by testing the differences between log of the determinant of covariance matrix for each group. From R's result, it shows that all three nulls will be kept with p-values greater than our alpha level 0.001 and it is sufficient to conclude that the covariance matrices by groups are equal.

Table 2. Univariate skew and kurtosis table

literature	group	n	mean	sd	median	min	max	skew	kurtosis
AveMath1	0	4818	487.42	88.78	485.32	145.05	781.83	0.07	0
AveMath2	1	2972	534.6	90.2	535.68	243.89	819.53	-0.09	-0.21
AveRead1	0	4818	494.42	87.23	497.81	65.34	751.82	-0.26	0.21
AveRead2	1	2972	546.84	88.02	551.37	204.56	769.93	-0.37	0.12
AveScie1	0	4818	504.09	91.86	503.86	63.26	804.96	-0.07	0
AveScie2	1	2972	554.06	91.9	558.6	221.78	822.21	-0.27	-0.07
poetry	group	n	mean	sd	median	min	max	skew	kurtosis
AveMath1	0	5062	494.13	89.7	491.87	145.05	787.12	0.07	-0.03
AveMath2	1	2728	526.36	93.18	526.84	238.99	819.53	-0.1	-0.23
AveRead1	0	5062	501.2	88.27	503.32	65.34	760.08	-0.25	0.23
AveRead2	1	2728	538.95	91.36	543.15	189.84	769.93	-0.36	-0.02
AveScie1	0	5062	510.43	92.04	510.39	63.26	804.96	-0.09	-0.04
AveScie2	1	2728	546.76	95.96	552.16	152.13	822.21	-0.28	-0.09
art	group	n	mean	sd	median	min	max	skew	kurtosis
AveMath1	0	2028	486.6	93.93	482.83	145.05	819.53	0.09	0
AveMath2	1	5762	512.04	90.69	511.54	173.87	801.69	0.02	-0.2
AveRead1	0	2028	489.94	93.15	492.87	65.34	760.08	-0.21	0.23
AveRead2	1	5762	523.03	88.86	526.31	135.67	769.93	-0.24	0.01
AveScie1	0	2028	501.12	96.82	499.57	63.26	804.49	-0.04	0.02
AveScie2	1	5762	530.91	93.16	534.07	152.13	822.21	-0.14	-0.17

4.2 Hotelling's T² Test

The null hypotheses for Hotelling's t-squared tests are groups come from populations with equal centroids. In the groups of literature, t-squared is 219.71 with p-value less than 2.2e-16. In the groups of poetry, t-squared is 108.08 with p-value less than 2.2e-16. In the groups of art, t-squared is 73.674 with p-value less than 2.2e-16. So, all nulls are rejected and the results indicate that students who have classic literature, book of poetry and works of art are or not do differ on the performance of mathematics, reading and science. The Mahalanobis distances which reflect the effect sizes are 73.22, 36.02, and 24.55, and they are large enough, and powers of these three tests are close to 100%. Therefore, it shows that students on average scored higher on these three subjects if they have literatures, books of poetry and works of art in their home.

4. RESULTS

4.1 Means by Groups

The Table 2 shows that When our predictors equal 1, which indicates that students have that item in home, the means of scores in Mathematics, reading and sciences are higher comparing with predictors equal to 0. And, the differences from groups of literature is bigger than those of poetry and art. However, differences range from about 50 to 30 comparing with the total of about 500 are not quite significant.

4.3 Three-Way Between-Subject MANOVA

After figuring out the differences between groups, MANAVA test in type III sums of squares is now used to test if there is any interaction effect. From the results as shown in table 3, while there are significant interaction effects, the main effects then will not be reported here. Thus, with alpha level of 0.05, the between-subjects MANOVA indicates there is no difference between the interaction of literature and art with Pillai's trace of 0.00033 and p-value of 0.013. And there is a statistically significant interaction effect from the interaction of literature and poetry, interaction of literature and art, and the three-way interaction. Thus, the differences between whether students have literatures on the performance differs by whether students have book of poetry, with $F(3, 7790) = 3.6$ and p-value of 0.013. The differences between whether students have works of art on the performance differs by whether students have book of poetry, with $F(3, 7790) = 3.8$ and p-value of 0.010. And, the differences between the

combination of whether students have works of art and books of poetry on the performance differs by whether students have literatures, with $F(3, 7790) = 2.7$ and p-value of 0.044. With

significant interaction effects, the three different items effect students' academic performance together.

Table 3. Type III MANOVA Tests: Pillai test statistic table

	Df	test stat	approx F	num Df	den Df	Pr(>F)	
(Intercept)	1	0.863	16336	3	7780	< 2.2e-16	***
literature	1	0.00805	21	3	7780	1.44E-13	***
poetry	1	0.00064	1.7	3	7780	0.17051	
art	1	0.00766	20	3	7780	6.50E-13	***
Literature : Poetry	1	0.00138	3.6	3	7780	0.013	*
Literature : Art	1	0.00033	0.9	3	7780	0.45797	
Poetry : Art	1	0.00145	3.8	3	7780	0.01031	*
Literature : Poetry : Art	1	0.00104	2.7	3	7780	0.04432	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1							

5. IMPLICATIONS

The results from above analysis support the original hypothesis that Students' performance in reading, mathematics and science are affected by the learning environment, especially the accessories in room by testing the effects of literatures, works of art and books of poetry.

Although, the effects from these items in home only contributes to a small part on students' academic performance, but we should still consider whether we should spend time in this manner to change students' performance with limit time and resources.

According to this study, in order to improve the students' academic achievement, it is necessary to perfect the evaluation method in PISA system and supplement the learning environment factors.

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