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MATH AND SCIENCE PERFORMANCE ON READING COMPREHENSION: A SYMBOLIC REGRESSION ANALYSIS

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Abstract:
Traditional techniques for analyzing the functional relationships between a set of predictors (x) and a response variable (y) assure linear models. In reality, however, such relationships are highly complex and non-linear. This study pursues a non-linear analysis of the relationship between math and science performance (x) and reading comprehension (y) using symbolic regression. Data from PISA (2015) were obtained and analyzed. Results revealed that while there is no consistency among students of different countries on their dominance over a subject area, their scores in the three areas as math, science, and reading comprehension are very close to each other. This means that for these students, the ability to perform in math is almost the same ability they can show in science and reading comprehension respectively and vice versa. It was found out that the students' performance in both math and science were highly correlated with their reading comprehension. Moreover, the combined math and science performances of the students had a very significant correlation with their reading comprehension. Thus, reading comprehension is highly correlated with the performance in math and science.

Key Words: *math, science, reading comprehension, PISA, symbolic regression*

Introduction:

Scientific, mathematical, and reading comprehension competences are needed in order to address and resolve the growing global gaps in the 21st century education, yet only limited literature reveals that attaining certain levels of competence in math and science show a significant relationship to reading comprehension. According to the findings of Lerkkanen, Puttonen, Aunola, and Nurmi (2005), mathematics and reading comprehension were very much linked with one another across both years. Additionally, the performance in mathematics projected consequent reading comprehension in the first year rather than vice versa. The results suggest that mathematical knowledge is integral prior to children's school entry to formal education.

Another study found out that math word problem performance is strongly associated to the reading comprehension performance among students (Tuohimma, Aunola & Nurmi, 2007). Likewise, competent technical reading abilities in math word problem increased the latter. Regardless of the level of technical reading involved, it was concluded that math word problems

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were still interrelated to reading comprehension, implying that both skills necessitate overall reasoning abilities.

Moreover, a dearth in literature showing the relationship of the performance in science to reading comprehension is observed even if the former has a long and close relationship with mathematics (Wright and Chorin, 1999).

To critically understand such phenomena, the study looks into the performance levels of the six participating continents and the countries representing them in the 2015 Programme for International Student Assessment (PISA). Furthermore, the 2015 PISA results will be subjected to symbolic regression analysis in order to elucidate for the significant correlation between math and reading comprehension; science and reading comprehension; and combined math and science and reading comprehension.

Methodology:

The study utilized quantitative research methodology which deals with quantifiable variables that systematically investigates a phenomenon. Leedy (1993) added that such method aims to explain, predict, and control a phenomena. In this manner, the researchers used data mining in order to gather the math, science and reading comprehension test results coming from the 2015 Program for International Student Assessment (PISA).

PISA is a triennial international survey which aims to evaluate education systems worldwide by testing areas in science, mathematics, reading, collaborative problem solving and financial literacy. Over half a million of 15-year-old students, representing 72 participating countries, joined the survey. Each examinee was asked to complete computer-based tests. Each student's responses were assessed for a maximum of two hours. The test items consist of multiple-choice questions and contextualized open-ended questions. Different students were asked to take different combinations of test items. All the test items for science, reading, mathematics and collaborative problem solving required each student 810 minutes to finish. The data was subjected to symbolic regression analysis using the formula $y = f(x)$ in Eureqa software where the reading comprehension was represented by the variable y, and math and science performance was represented by variable x.

Findings:

Table 1.

2015 PISA Results

Continent	PISA Performance			
	Mathematics	Science	Reading Comprehension	SD
Africa	363.50	381.00	355.50	13.00
Asia	469.00	472.90	457.00	1.95

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Australia	494.50	509.50	506.00	7.85
Europe	475.92	463.36	473.44	6.65
North America	424.40	481.40	446.40	28.70
South America	409.63	455.63	431.63	23.00
Average	439.49	460.63	444.99	13.53

Table 1 presents the 2015 PISA performance of the participating countries clustered into their continents.

The 2015 PISA results could be analyzed by looking through at each continent's participating countries' performance. Australia, being both a continent and a country, is joined by New Zealand. Their combined scores topped the ranking across all subject areas in math, science, and reading comprehension by continent. Though by country, both countries only made it to the 10th to 20th ranks in all subject areas. It registered a standard deviation of 7.85 which means that their scores in the three areas are so close. This further means that their performance in math and science can be used to tell their performance in reading comprehension. Based on the researchers' comparative curriculum analysis, both countries require students, starting from the foundation year, to master first the fundamental competencies across disciplines prior to their progression through the curriculum. Such implementation is necessary in order for the former to attain the achievement standards, in the 8 learning areas, that they set for students in every band of years that they attend in school. Their achievement standards aim to holistically develop productive and educated citizens. On the other hand, the latter aims to infuse the values and competencies into their 8 learning areas so as to develop positively competent, flexible, and sociable life-long learners. It was also discovered that both curriculum required focused teaching in math, science, and English so as to perpetually develop reading and literacy skills, numeracy skills, and scientific knowledge in order for their students to apply their learning in real-life situations. Hence, both curriculums clearly manifest that achieving the fundamental standards first is the key in succeeding the PISA exam.

Europe placed second in the over-all 2015 PISA results. It is a continent located entirely in the Northern Hemisphere and mostly in the Eastern Hemisphere. It finished second in both math and reading comprehension but landed on the 4th spot in science. Out of 36 participating European countries, only Finland is consistent in making it to the top 10 of 73 countries in all subject areas. The rest of the countries were not performing well but their scores among subject areas were very close making only a 6.65 standard deviation. This means that though their scores were not that high, their performance in the three areas were almost the same. According to PISA and Sahlberg (n.d.), lesser students perceive math as a difficult subject. This is due to the fact that reading in Finland is highly encouraged. It is the highest country to publish children's book compared to other countries. Their curriculum focused on the teachings of numerical, scientific and reading literacy as early as childhood education which paves way to making Finland being consistent in the math, science and reading comprehension 2015 PISA results. The major reason for these high learning results in Finland is that all teachers are required to attain a master's

degree level which comprises for a 5-year program. Finland is aiming for an educational policy with high standards of teachers to achieve quality education.

Asia only ranked third in the over-all rankings and in all subject areas. Singapore ranked 1st in all subject areas among 73 countries. This is because in Singapore, teachers make sure that the coverage for the curriculum is met without sacrificing mastery over the subject matter. This is done by doing a lot of drills and exercises in order to pass the national examinations which are administered at the end of both elementary and secondary levels. If they fail in the said exams, they will not be admitted to the next academic level. Furthermore, in this country, old school pedagogies are practiced the most. As opposed to the contemporary styles, the Singaporean education believes that in order to attain a higher level of learning, teaching should be teacher-centered. Students are only to listen and the teachers have to do the most, if not all, of the talking (Hogan, 2014). This is possible because it takes only the most intellectual to become a teacher. This practice reflects the rigid screening process of Singaporean universities as they admit students to enroll in their education programs. Unlike in the Philippines, not all aspirants can be admitted for teacher education programs as the Singaporean government will set a limit of enrollees, one out of eight in most cases, based on the number of teachers the country needs. Most of the countries in the top 10 in the 2015 PISA are actually from Asia (e.g. China, Japan, Hong Kong, and Korea). Japan offers five different types of high schools: elite, which consists the cream of the crop who upon graduation are recommended to top national universities; non-elite, the mainstream high school, which is the preparatory school for less prestigious universities; vocational high schools, 60% graduates of which enter a full time employment after completion; correspondence high school which is equivalent to Philippines's Alternative Learning System (ALS); and evening high school for the working students (Kawagoe, 2016). Out of these five types, only the elites were enjoined in the 2015 PISA and so a good result was expected. Even with the forces of Singapore and Japan, Asia only ended 3rd in the over-all ranking of continents. This means that while some of the participating Asian countries excelled in the exams, many had poor performances. Despite that, Asia's mean scores in all subject areas registered the lowest standard deviation value of 1.95. This means that the Asian countries' performance in a subject area is almost the same performance they have in the other two areas; that when they excel in math they also excelled in science and reading comprehension respectively, and vice versa.

North America placed 4th in the over-all ranking though it ranked 2nd in science. It is represented by five countries with Canada (finishing as over-all 2nd placer), Costa Rica, Dominican Republic, and Mexico (in the over-all bottom 15), and United States (placing between 20th – 30th ranks). It registered the highest value of standard deviation of 28.7 which means that their scores in the three subject areas varied to a slightly high degree. It can further be analyzed that their performance in math or science cannot be used as an indicator of their performance in reading comprehension and vice versa. The overall PISA results in North America can be attributed to the efficacy of educational curriculum implementation and support. Canada, one of the top performers in PISA, clearly shows a great disparity from its neighboring

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countries: United States, Costa Rica, Dominican Republic, and Mexico, which have only placed the lower and bottom ranks respectively. According to OECD (2015), the main factors leading to the high education performance of Canadians are access to early childhood education and care (ECEC), fair and inclusive policies enabling all students to study public primary and education for free, positive learning environments, low dropout rate, and higher level of instructional leadership. However, the results of Canada with that of the United States is quite higher even if both countries belong to the first worlds. The lowering results of the US' performance in PISA can be linked to the special problems in urban schools. These problems are poverty, low attendance, lack of discipline, and physical and sexual abuse by adults at home or school that have hindered success among students since their well-being is disrupted (Trelfa, n.d.). On the other hand, Costa Rica, Dominican Republic, and Mexico are placed in the bottom ranks because they have not effectively attained the aforementioned factors observed in the former. OECD (2017) affirmed that the main factors affecting the performance of Costa Rica are poverty, unequal access to services in early childhood education, high dropout rates, and unattained improvement in their education systems. In addition, Dominican Republic also faces the same dilemma. According to Education Policy and Data Center (2007), the educational attainment is low among the youth, ages 15-24. The data set revealed that 2% has no education, 28% has not completed primary education, and 38% has not completed secondary education. Moreover, the repetition rate in the primary grades is 7.7% which is quite disturbing. This reflects negative implications to the academic performance of their primary graders. Furthermore, the educational system in Mexico does contribute a limited impact in reducing inequality since indigent students, unlike other rich countries, seem to experience recurring problems such as repeating grades, dropping out, and inaccessible access to higher education (Puryear, Santibañez, & Solano, n.d.). This explains why Mexico ranked low in overall quality of the education system (120th out of 139). Similarly they are also low in quality of primary education (120th), and quality of science and math education (128th) (Puryear, et al., n.d.). Hence, educational performance precedes an effective implementation of educational policies, curriculum, and support.

South America placed 5th in all subject areas and in the over-all ranking. Represented by eight countries, it only has Colombia to brag which finished 4th in science. The main core in Colombia's educational system lies within a student-centered curriculum. This is clearly shown in almost every school system in Colombia that their science teachers adapt their everyday lesson according to each students' needs and prior knowledge. There is a one to one ratio of computers in Colombia for every student in their science department which clearly shows that their science lab is given more budget. Students learned a lot of scientific concepts, even raised more interest in science because of their exposure in joining science-related extra-curricular activities in school. The manner of teaching is more focused on science performance and students' expectations of working into a science related career as compared to other subjects. The remaining countries ended on the bottom 20 in all subject areas. With a standard deviation of 23, their scores in the three areas also varied slightly high. This means that their level of performance in one subject area cannot be used as a predictor for their performance in another

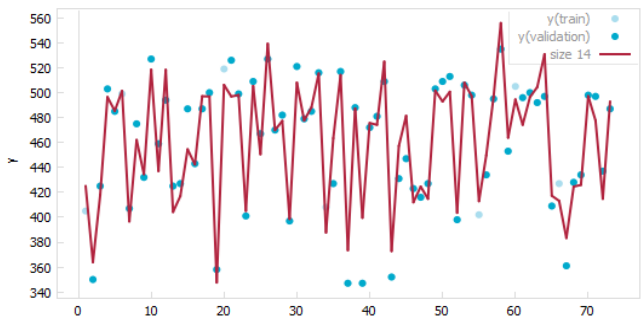
area. This is best explained by Colombia's performance; it ranked 4th in science but only placed 64th in math and 56th in reading comprehension. Math lessons in South America in general focused primarily on the presentation and repetition of math procedures. Hence, students are not encouraged to expand their critical thinking skills explaining their 64th rank in math.

Africa ranked 6th in all subject areas and in the over-all ranking of continents. It is represented by Algeria and Tunisia which ended in the bottom 5 in all subject areas. With a low standard deviation of 13, Africa's performance in the subject areas were close. Malnutrition or income deprivation is one of the many reasons why students in Africa have learning gaps. This is due to the fact that poverty is at the heart of Africa's main problems. This resulted to lack of proper school facilities that resulted to unequal opportunity for education. Based on the study made by UNESCO Institute for Statistics that over one-fifth of the children between ages 6 and 11 are out of school, followed by one-third of youth between the ages of about 12 and 14. Six out of ten of the youth between the ages 15 and 17 are not in school. OECD projected that it could take 180 years for Tunisia to reach the OECD average for math. In addition, absenteeism of teachers is attributed to low salary resulting minimal learning outcomes. Their rank in the bottom 5 in all areas proved that their performance in math or science can be used to predict their level of reading comprehension. The results revealed that while there is no consistency among students of different countries on their dominance over a subject area, their scores in the three areas as math, science, and reading comprehension are very close to each other. This means that for these students, the ability to perform in math is almost the same ability they can show in science and reading comprehension respectively and vice versa.

The results revealed that while there is no consistency among students of different countries on their dominance over a subject area, their scores in the three areas as math, science, and reading comprehension are very close to each other. This means that for these students, the ability to perform in math is almost the same ability they can show in science and reading comprehension respectively and vice versa. Akbasli et. al (2016) affirmed this in his study that students who are successful on reading also show great success on math & science classes.

Figure 1.

Test of Significant Relationship between Math and Reading Comprehension Using Symbolic Regression



Solution	y = 57.49 + 0.8753*x - 9.392*cos(-5.741*x)
R^2 Goodness of Fit	0.89551504
Correlation Coefficient	0.94661386
Maximum Error	52.578597
Mean Squared Error	263.05987

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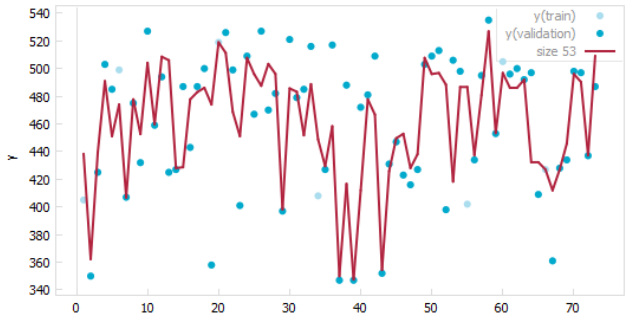
Figure 1 shows the test of significant relationship between math and reading comprehension using symbolic regression.

Based on the figure, math and reading comprehension are correlated by 95 percent. This meant that for these students, their math performance can be used to gauge their performance in reading comprehension and vice versa. This further meant that a student with high score in math will also have a high score in reading comprehension. This finding is supported by the study of Lerkkanen, Puttonen, Aunola, and Nurmi (2005) which revealed that mathematics and reading comprehension were highly associated with each other because both require good reasoning.

The fluctuation in the figure meant that while it is true that mathematics performance and reading comprehension were highly correlated, the performance of the 73 countries greatly varied from each other. Some excelled, many scored average, while some flanked. This is because each country has a unique educational system. Singapore, being the topmost performing country, has English as one of the official languages and so reading comprehension was no issue. The other top-performing countries like Finland, Japan, China, Belgium, Korea and Vietnam are not English speakers yet fared well in the 2015 PISA. This meant that with the right curriculum, a country can perform well in English even if it is not its first language.

Figure 2.

Test of Significant Relationship between Science and Reading Comprehension Using Symbolic Regression



Solution	y = 138.2 + 0.6948*x - tan(140.4 + x) - tan(276.6 - x) - tan(-0.7986 - x) - tan(13.32*x) - tan(11.68*x) - tan(0.6892*x)
R^2 Goodness of Fit	0.5287921
Correlation Coefficient	0.73289861
Maximum Error	116.02055
Mean Squared Error	1186.3515

Figure 2 presents the test of significant relationship between science and reading comprehension.

As revealed, the students' science performance is 73% correlated with their reading comprehension. This meant that their performance in science can be used to predict their reading comprehension; that when their science performance is high, their reading comprehension is expected to be high and when their science performance is low, their reading comprehension will also be low.

While there is a high correlation between science and reading comprehension, the difference in their scores is quite alarming. Most of the countries performed above average while a few fared very low in the 2015 PISA. This meant that across countries, since curriculum is not

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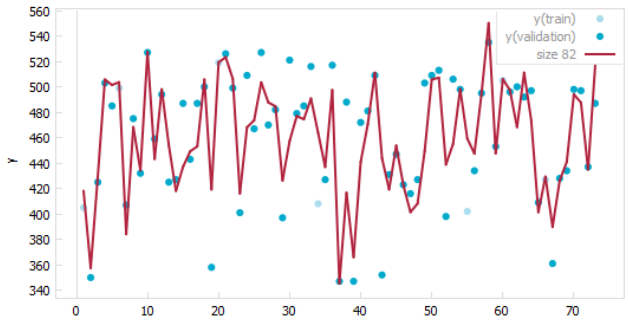
universal, each country has to look into its educational system and try to investigate what the top performing countries are doing on this regard. Each has to initiate an item analysis based on the PISA results.

Figure 3.

Test of Significant Relationship between the Combined Math and Science Performances and Reading Comprehension Using Symbolic Regression



Solution	y = 24.35 + 0.9544*x + 1.297*tan(-2.135*x) + 5.101*tan(153.6 + cos(x)) - 1.194*tan(164.9 + x^2)
R^2 Goodness of Fit	0.72486347
Correlation Coefficient	0.85314678
Maximum Error	91.779969
Mean Squared Error	692.70617

Figure 3 reveals the test of significant relationship between the combined performances in math and science, and reading comprehension.

Using symbolic regression, at 100% convergence, the reading comprehension of the students is 85% correlated to the averaged performance in math and science. This means that the math and science performances of the students had a very high correlation with their reading comprehension. In other words, the higher their math and science scores, the higher is their reading comprehension and the lower their math and science scores, the lower is their reading comprehension.

Results revealed that when one performs well in math and science, one is likely to perform well in reading comprehension. This further revealed that both verbal (reading comprehension) and non-verbal systems (math and science) can simultaneously be ignited. But this can only be done if children have been long immersed and engaged in both systems. Hence, it is deemed necessary that pre-school children must instantaneously be taught with math, science, and reading comprehension in order for them to learn and master these subjects as they progress through its levels, as what is mostly done by the top-performing schools in PISA. This then contradicts the notion that one can be dominant in only one system, either verbal or non-verbal.

Conclusion:

A nation's success in the implementation and actualization of their educational policies, curricula, and learning outcomes is reflected on their regard in fostering mastery among the

interrelated disciplines in math, science, and reading comprehension, as manifested from their PISA results.

Suggestions and Recommendations:

While the study is successful in revealing the significant correlation between math and reading comprehension, science and reading comprehension, and math and science combined performance and reading comprehension, it is recommended that an in-depth study of the educational systems of each participating country and a background check on the students' profile be initiated. The Philippines is also enjoined to take the 2018 PISA as this is one of the best ways to assess the current educational system of the country. This will evaluate how the younger generations are faring in their respective schools and how globally competitive they are. A comparative analysis on educational policies is also recommended, especially with the top-performing countries like Singapore, for benchmarking purposes.

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