CLUSTER CHARACTERIZATION OF COUNTRIES' PERFORMANCE IN MATHEMATICS OLYMPIAD: INPUT TO MATHEMATICS EDUCATION

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ABSTRACT: *Several factors influence a country's performance in mathematics competitions. The factors considered in this study are English language proficiency, technological readiness level, and the quality of mathematics and science education. Researchers mined the global competitiveness index for data sets on countries' mathematics and science education quality and technological readiness. In addition, researchers used the Global English proficiency index to determine language proficiency and international mathematics Olympiad scores for Olympiad results. Groupings based on the performance characteristics of the identified sixty countries emerged using the k-means clustering method. The algorithm produced three major clusters separating poor, average, and best-performing countries in the international mathematics Olympiad performance context. Poor-performing countries exhibited a lack of English language proficiency, inadequate mathematics and science education, and a lack of technological readiness. Average-performing countries have high levels of technological preparedness, moderate English language proficiency, and average-quality mathematics and science education. The best-performing countries had high English language proficiency and quality mathematics and science education but not necessarily a high level of technological readiness. Furthermore, the findings revealed that mathematics and science education quality is significantly related to English language proficiency and technological readiness. It is also worth noting that the mathematics Olympiad performance is multi-dimensional, and no single factor can explain it. It is a challenge to consider aligning how students are trained for the mathematics Olympiad and the teaching of mathematics in the classroom.*

Keywords: Language Proficiency, Science and Mathematics Education, Technology Readiness

INTRODUCTION

The Mathematics Olympiad is an international competition in which countries send high school pupils to be evaluated on their mathematical knowledge and skills [1]. It is hosted annually in a different country and overseen by a board to ensure that the host country follows the contest's rules and traditions. Progressive ideas in algebra, geometry, pre-calculus and other math subjects for high school students are covered in this competition. To be eligible for the competition, many students underwent extensive training to improve their grasp of the topics.

Various organizations in the Philippines organize training programs and student selections to compete in the Olympiad. The Philippine Mathematics Olympiad (PMO), organized by the Mathematical Society of the Philippines, aims to improve mathematics education in the country by arousing more significant interest in and appreciation of mathematics among students and teachers [2]. It is the Philippines' oldest and most renowned national mathematics competition for students, where the country's representative to IMO is bred [3].

The Olympiad performance of the student representatives is viewed as a reflection of their country's mathematical prowess. Countries that perform well in this competition are regarded as industry leaders in their respective industries. On the other hand, those who perform poorly must improve to catch up to those who do well. Berg states that the top countries' performance indicates a long history of high-level mathematical problem-solving [4]. Based on the overall results, China, Russia, and the United States of America are regarded as powerhouses, according to statistical analysis of the worldwide Mathematics Olympiad results.

In 2009, Henseke attempted to explain why countries performed differently at the International Mathematical Olympiad [5]. To understand country differences in average achievement, he investigated the macro-level factors of Olympians' performance at the IMO. Population growth and dynamics, economic resources, human capital, schooling quantity and quality, and political regime were all factors. The findings show that macro-conditions can explain cross-country disparities well but cannot predict performance changes over time. As a result, long-term differences in country characteristics are linked to Olympians' average performance.

Some of the factors found in previous research that may affect participating countries' mathematics Olympiad success include the quality of mathematics and science education, English language competency, and technological readiness. However, few studies show the importance of these elements in Olympiad performance. This paper attempted to fill up the gaps and investigate the argument.

Factors like English language proficiency, technological readiness level, and mathematics and science education quality are investigated as to how they relate to Olympiad performance. Campbell and colleagues spent 11 years tracking down 1,093 Olympians from six nations to learn about their careers, accomplishments, and the variables that contributed to their success [6]. The quality of mathematics and science education in the academic competitions demonstrated to have a significant impact on their successes.

Shohamy mentioned that English is used extensively in various fields, including business, academia, journalism, education, and everyday encounters [7]. Furthermore, according to Rambely and colleagues, solid command of English is required to comprehend Mathematics [8]. Aside from English language proficiency, technological readiness is a crucial component of Olympiad success. According to Harris and the company, technology plays a critical role in student accomplishment in the face of numerous worldwide advancements [9]. According to Jhurree, technology is decisive in promoting economic, social, political, and educational reforms [10].

With these factors, the research aimed to identify cluster features based on the performance of participating countries in the Mathematics Olympiad in terms of English language competency, mathematics and science quality, and technological preparedness. Furthermore, the relationship between the cited factors was determined. This study aims to capture the features of participating nations' performance to assist low- and average-performing countries in improving their policies, projects, and programs to catch up with high-performing countries.

MATERIAL AND METHODS

This quantitative study utilized the k-means clustering method to group countries with similar characteristics in terms of Mathematics Olympiad performance. According to International Business Machines, this procedure uses an algorithm to identify relatively homogeneous groups of cases based on selected characteristics [11]. The k-means approach, which uses an explicit distance metric to partition the data set into clusters, is the most extensively used clustering algorithm. Also, correlation analysis was done to determine significant associations among the variables.

With data mining, the quality of math and science education and technological readiness are taken from Schwab's global competitive index 2017 – 2018 [12]. The language proficiency was taken from the global English Proficiency Index provided by Education First [13]. As for the Olympiad results, the raw scores of the International Mathematics Olympiad 2017 were considered [14]. The researchers were able to clean the datasets and identify sixty participating countries.

RESULTS AND DISCUSSION

The countries were divided into three partitions considering the International Mathematical Olympiad results in technological readiness, English language proficiency, and mathematics and science education quality. Based on the results provided in table 1, it is evident that the first cluster made outstanding Olympiad results compared to the other two groups. It further shows that this group has the highest English language proficiency and the most advanced mathematics and science education quality. These have been two contributing factors that resulted in the impressive Olympiad scores.

Many participating countries like Germany, Singapore, Japan, and Hong Kong belong to cluster 1. These clusters of countries have relatively high technological readiness status as they are highly developed countries. However, the same group belongs to many developing Asian countries like the Philippines, Iran, and Indonesia. This difference shows that the countries in this cluster may not necessarily need a high technological readiness to ace the mathematics Olympiad.

Furthermore, the first cluster lists most countries that can speak and comprehend English. Being proficient in English may be a strong suit in Mathematics competitions. Henry and his colleagues support this analysis, emphasizing that English proficiency is a significant predictor of Mathematics scores [15]. Adding up to the discussion, many of the countries belonging to the group are members of the top-tier PISA 2015 ranking. It reflects in these countries not only the exceptional skills in reading but also the quality of education in Mathematics and Science is outstanding.

Table 1. Olympiad Performance Clustering of Countries

Variable	Cluster 1	Cluster 2	Cluster 3
Number of Countries	25	10	25
English Proficiency	55.77	48.85	54.99
Quality of Math and Science Education	4.46	3.08	4.24
Technological Readiness	4.79	3.73	4.91
Mathematics Olympiad Score	120.96	37.50	84.84

Cluster 1 China, Iran, Japan, Singapore, Thailand, Taiwan, Russia, Greece, Czech Rep., Ukraine, Philippines, Bulgaria, Italy, Netherlands, Serbia, Hungary, Poland, Romania, Kazakhstan, Argentina, Bangladesh, Hong Kong, Peru, Indonesia, Germany

Cluster 2 Venezuela, Costa Rica, Pakistan, El Salvador, Nigeria, Uruguay, Guatemala, Panama, Cambodia, Egypt

Cluster 3 Turkey, Brazil, Malaysia, France, Saudi Arabia, Azerbaijan, Mexico, Mongolia, Sweden, India, Portugal, Spain, Switzerland, Colombia, South Africa, Belgium, Sri Lanka, Denmark, Morocco, Austria, Norway, Algeria, Lithuania, Chile, Ecuador

Singapore, for example, is consistently on the top rank among the sixty participating countries in the PISA 2015. It is well-known that this country built a world-class education system, eventually outperforming many institutions worldwide. They invested in the employability of competent teachers with continuous support for professional development [16]. Thus, the move uplifted the quality of education in the country. Caingcoy and colleagues mentioned that classroom instruction, like science and mathematics education, has to consider employable skills [17].

A viewpoint shows that the Philippines somewhat showed an outstanding performance in the IMO despite the lack of good resources. Although the country belongs to cluster 1, it is rating in the indices used in this study may be far behind compared to other countries in the same cluster as Singapore, Hungary, Germany, and Japan. It only shows that the Philippines can still significantly improve its technological readiness, quality of education, and English language proficiency. With this, the country may attain a better spot in the IMO.

Looking at the second cluster, it is very noticeable that countries belonging to this partition lagged in the IMO 2017 competition. This table further reflected its lack of proficiency in the English language, low educational quality in Mathematics and Science, and the apparent inferiority in the technological readiness of the ten countries. It is inarguable that all these three variables led to cause poor IMO results. Venezuela, Costa Rica, Pakistan, El Salvador, Nigeria, Uruguay, Guatemala, Panama, Cambodia, and Egypt may need to enhance their proficiency in English, their quality of education, and the readiness of technology availability and usage to improve IMO performance.

Math education in Cambodia is plagued by a lack of competent teachers, curriculum creation, textbook authorship, teaching methods, and ICT use [18]. No mechanism exists to verify that Cambodia's mathematics education meets international standards. The Cambodian Mathematical

Society identified priority goals for the country, like enhancing the mathematics curriculum, encouraging information and communication technologies, and fostering participation in international mathematics competitions and programs.

Academics, national educational authorities, and English teachers at different levels of education have debated the status and role of English in Venezuela for the past years. Despite advancements and the relevance of the English language to other subject areas like Mathematics and Science, Gamero cited that change is being resisted in how English is taught [19]. In Egypt, Science and Mathematics are to be taught in the English language starting in 7th grade, according to Education Minister Shawki [20].

In the interest of the third cluster, a high point level of technological readiness, moderate levels of English language proficiency, and quality of science and mathematics education were reflected. Countries like France, Spain, Switzerland, and Norway belong to this cluster. It can be inferred that high technological readiness did not translate into top performance in the Olympiad. In learning Mathematics, advanced technologies are encouraged in the classroom but must be checked on their appropriateness. The complementary use of cellphones, computers, calculators, and many other gadgets in the classroom must be aligned with the mathematical competencies and concepts. It is supported by the study of Penaso and Gaylo that there is no significant difference in the mathematical aptitude of learners when grouped according to the levels of exposure and interactivity of mathematics-related computer games [21]. The nature of competitions is to demonstrate mastery of problem-solving and critical thinking skills independent of gadgets. It may indicate that utilizing advanced technology may give leverage in the education curriculum but may not necessarily secure mastery and competence. It, in turn, provided an average IMO performance compared to the first cluster. This further implies that countries in the third cluster have an avenue to improve their language proficiency and the quality of Mathematics and Science Education.

Table 2. Relationships among Variables

	English Proficiency	Quality of Math and Science	Technological Readiness	Mathematic Olympiad Score
English Proficiency	-			
Quality of Math and Science Education	0.438 *(0.014)*	-		
Technological Readiness	0.557 *(0.002)*	0.728 *(0.000)*	-	
Math Olympiad Score	-0.241 *(0.123)*	0.223 *(0.142)*	-0.033 *(0.438)*	-

Note: The p-value is the one italicized and placed in parenthesis.

To go deeper into the relationships between English proficiency, quality of mathematics and science, and technological readiness toward mathematical Olympiad scores, table 2 presents the correlation values and significance. Table 2 reveals a significant positive relationship between the participating countries' quality of mathematics and science and English proficiency. It supports the study which claims that mathematics scores increase simultaneously with English proficiency [15]. It implies that the better quality of the curriculum is given to the Science and Mathematics, the more proficient one is in English. It goes the other way around where the decline of the curriculum in Science and Mathematics could mean a lack of mastery of the English language.

Further, a strong positive correlation exists between technological readiness and mathematics and science education quality. It only makes sense since technology has been integrated into Science and Mathematics. The technological applications enable students to visualize scientific and mathematical concepts. It can be said that technology is a product of both Mathematics and Science. It corroborates the study of Bungum and the company as they emphasized the role of technology and design and its involvement in Science and Mathematics projects [22]. Gaylo mentioned that the interplay of quality education in science and mathematics and other factors dictates the countries' level of innovation in the global economy [23].

Also, it is noteworthy that the mathematics Olympiad is not significant to the considered factors when taken individually. This observation connotes that the performance in the mathematics Olympiad is multi-dimensional. It cannot be explained singularly but in its plurality.

Table 3. Significant Relationships by Cluster

Significant Relationships	Cluster 1	Cluster 2	Cluster 3
Quality of Mathematics and Science Education - English Proficiency	0.438	0.815	0.467
Quality of Mathematics and Science Education – Technological Readiness	0.728	0.758	0.539
Technological Readiness- English Proficiency	0.557	0.795	0.716

Looking closer at significant relationships, it can be gleaned from table 3 that when investigated by cluster, results revealed that the second cluster, composed of low-performing countries in the International Mathematics Olympiad, had the highest positive correlation in all significant emerging relationships. Low-performing countries in Mathematics Olympiad need to consider the influence of one factor on another because the significant influence of one another will translate to high performance. Table 3 shows the importance of these factors in their performance outcomes.

CONCLUSION AND RECOMMENDATIONS

The findings of this study indicate that countries competing in the International Mathematics Olympiad must consider the interplay of English language proficiency, technological readiness, and the quality of Mathematics and Science education to compete with other countries. It is also demonstrated that countries in Cluster 1 have high levels of English proficiency and science and mathematics education.

Cluster 2 countries demonstrated a high level of technological readiness. They may, however, need to prioritize improving their English proficiency and the quality of their mathematics and science education. Countries in Cluster 3 have poor quality mathematics and science education, technological readiness, and language proficiency compared to the other two clusters. Countries should consider the urgent need to improve these cluster 3 areas.

The relationships between the variables toward performance in the mathematics Olympiad were tested, and there was a significant correlation between all participating countries' technological readiness and English language proficiency. A significant correlation was also discovered between the quality of Mathematics and Science education toward English language proficiency and technological readiness. An intriguing finding revealed that mathematics Olympiad performance is multi-dimensional, and no single factor considered can explain it.

It is necessary to consider aligning how mathematics is taught for the Olympiads and mathematics education in the participating countries. The best practices in Olympiad preparation should be studied further to be adopted in Math teaching, as observed and evident in top-performing countries. With the Philippines' outstanding performance, the practices, strategies, and techniques shared with Filipino Olympians may be extended in the classroom. Teachers must know how students are trained in competitions to incorporate them into their classes.

Also, to enrich the preliminary findings of this study, another study with a different research design and scope may be conducted. Multiple points of view are required to comprehend the multi-dimensional construct of Olympiad performance fully.

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