DOES THE MEDIUM OF INSTRUCTION GUARANTEE THE PRODUCTION OF MORE SCIENTISTS, ENGINEERS AND RESEARCHERS?: WORLDWIDE FRACTAL DIMENSION ANALYSIS

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ABSTRACT

The study explored the implications of using the mother-tongue as a medium of instruction which is provided for in the K+12 law on the production of more scientists, engineers and researchers crucial in the country's bid for global competitiveness. Data from the World Social Statistics Report in 2012 were used for the fractal dimension analysis. Findings revealed that the use of mother-tongue in many countries across the globe resulted in more diverse production of this crucial manpower (some countries in this category produced more but other countries in the same category produced less). The exclusive use of English as a medium of instruction, on the other hand, guaranteed a more uniform production of engineers, scientists and researchers for several countries all over the world.

Keywords: *mother tongue, medium of instruction, fractal analysis, global competitiveness*

1.0 Introduction

Science and mathematics education is crucial in developing a national culture of scientificity which in turn accounts for a country's global competitiveness (GCI, Report 2013). Of late, there has been a resurgence of interest on factors that directly impact on students' science and mathematics performance. Among the factors that are identified as primordial to science/mathematics learning is the medium of instruction. Republic Act No. 10530, otherwise known as the K+12 law, explicitly requires the use of mother-tongue in the early education of Filipino learners. Implicit in this ordinance is the assumption that "a learner learns best" in his/her mother-tongue. This study aims to find evidence for or against this assumption using the performance of students from countries whose medium of instruction is the mother-tongue and those for which the medium is English.

Mimaropa (2009) found out that the use of the native language as a medium of instruction is the fastest and most natural route towards developing a strong foundation in mathematics literacy. Cabug-os (2011) affirmed that there is really a need to implement the Mother Tongue Based- Multi Lingual Education especially in all the school in the Philippines. Results of the studies show that when teachers use the pupils' mother tongue, they learn to read more

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quickly; learn better in Math and Science; and improve in cognitive skills. It has also been observed that there is a high level of participation among children in the classes where mother tongue is used as the medium of instruction. Children are able to understand what is being discussed and answer questions asked of them. Through these, an opportunity to develop higher thinking skills is made available and serves as a bridge in learning the national language easily.

However, Nilla (2002) found a contrary result on the relationship between language and mathematics achievement of the Filipino 7th graders of which the data of TIMSS-R of 2001 were analyzed based on the Mathematics achievement of students who took the English version and the Filipino version of the test. Results showed that students who took the English version test performed significantly better than those who took the Filipino version test in five content areas.

Considering the conflicting conclusions derived by various authors on the subject, it is expedient to re-analyze the situation using a more powerful approach. The approach that will be used in this study is the fractal analysis approach. Moreover, instead of using scores in Mathematics and Science of students across the globe, the study prefers to analyze the ultimate outcomes of education, namely, the number of scientists and engineers produced by the education system, as well as the number of researchers. These measures are far more indicative of the levels of science and mathematics performance of students either using their mother tongue or English. Since medium of instruction is one of the vital determinants to students' performance in math and science, hence, fractal dimension of students' achievement should be analyzed.

2.0 Basic Concepts in Fractal Statistics

Fractal statistical analysis was applied to conditions where the mean or first moment did not occur. It was also applicable to situations where smaller fluctuations overruled the larger ones. Padua (2012) recommended the use of a power law distribution which was similar to Pareto's distribution as given:

$$1....f(x) = \frac{\lambda-1}{\theta}\left(\frac{x}{\theta}\right)^{-\lambda},\ \lambda > 0,\ \theta > 0,\ x \geq \theta$$

where λ defined as the fractal dimension of X and θ was the smallest (positive) value of the random variable.
The extreme likelihood estimator of λ is:

$$2.... \hat{\lambda} = 1 + \frac{1}{\log\left(\frac{x}{\theta}\right)}$$

so that each observation contributed to the fragmentation of the support X. Padua (2013) established that the distribution of the maximum likelihood estimators conformed an exponential type of distribution so that both the mean and variance of the fractal dimensions exist.

A device called fractal spectrum or λ(s) spectrum was suggested by Padua et al., (2013) to identify locations on the support X where high data roughness or fragmentation occur and where smoothness appear to dominate. The spectrum defined as:

$$3... \lambda(s) = 1 - \frac{\log(1-\alpha)}{\log\left(\frac{x}{\theta}\right)} = 1 - \frac{\log(1-\alpha)}{s}$$

where X_a is the ath percentile of X and $s = \log\left(\frac{x}{\theta}\right)$

Deviations from smoothness explained the severity of fragmentation in the output measures in a given context. A test for deviation from smoothness i.e. H_0: $\lambda = 1$, was proposed in the second paper of Padua (2012).

3.0 Research Design and Methods

To determine the fractality of the ultimate outcomes of education, the number of scientists and engineers produced by the education system, as well as the number of researchers provided for the year 2002 – 2011 in different countries were obtained (Social Statistics Report, 2012). The purpose is to examine how the fractal dimensions of the output measures (scientists/ engineers and researchers) compare across countries using English and Mother-tongue as medium of instruction.

A one-dimensional plot of the researchers and the number of scientists and engineers in a given year from the Social Statistics Report (SSR). The plots was used as input to a fractal software FRAK.OUT available as a freeware from the NET. The output was a fractal dimension for the data set. Thus, three (3) fractal dimensions are obtained: fractal dimension for Mother-Tongue Medium, fractal dimension for English Medium and fractal dimension for Mixed Medium of instruction.

The deviation from smoothness:

$$4.... \quad d = (\lambda - 1) \times 100\%$$

was computed for each fractal dimension. The higher the percentage deviation was, the more severe the availability in outputs from each of the three (3) types of countries.

Finally, the researchers sought to locate the areas of high fractal dimensions (more pronounced in the education system) and relatively smoother areas by computing for the fractal spectra of each data set. The fractal dimension were then compared using Analysis of Variance (ANOVA).

4.0 Results and Discussions

Figures 1 to 3 show the one-dimensional plots for the number of scientists/engineers and researchers for countries whose medium of instruction is the mother-tongue, mixed medium or English medium. These one-dimensional plots were used as bases for computing

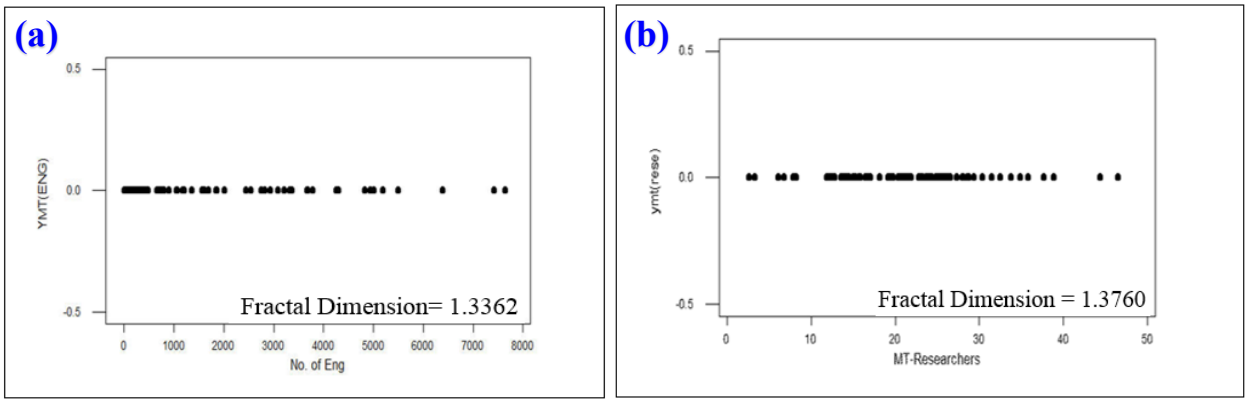

Figure 1. One-dimensional plot of (a) scientists/engineers and (b) researchers for mother tongue medium.

the fractal dimensions of the criterion measures, namely: number of engineers and scientists, and number of researchers in 180 countries all over the world.

Results show that countries using their mother tongue as medium of instruction in universities and colleges tended to have the most varied outputs in terms of the number of scientists and engineers produced as well as on the number of active researchers. Meanwhile, countries using English as medium of instruction have more uniform outputs in both criterion measures. In other words, a great deal of variability is observed in the number of scientists and engineers produced in countries using the mother tongue i.e. some of these countries produce a large number of scientists and engineers but other countries in the category are producing only a small number of scientists/engineers. The use of mother tongue as medium of instruction in schools is, therefore, no guarantee that there will be more of technically- oriented science and mathematics students getting into the career paths of engineering or sciences. In fact, it appears that the use of English as medium of instruction is a better guarantee for enticing more students into these career paths.

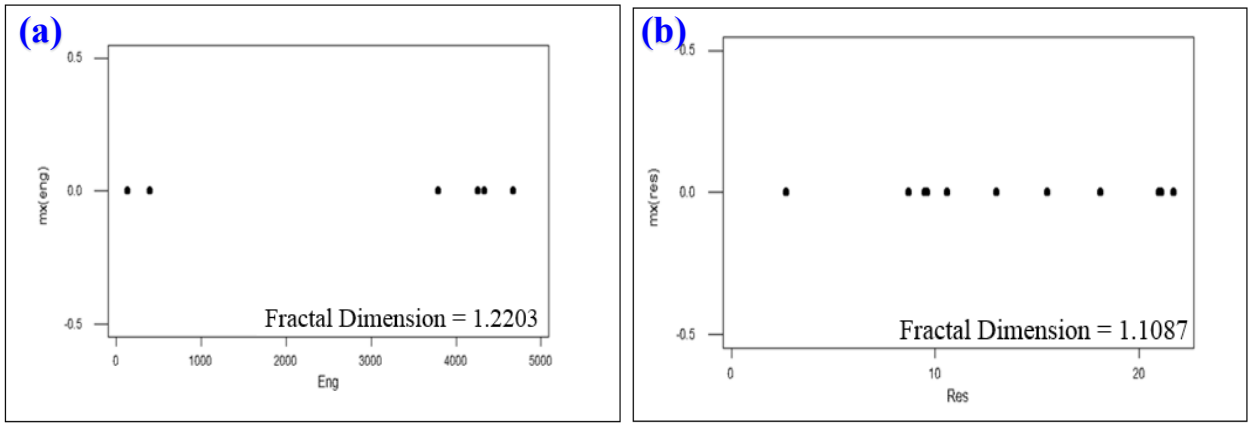

Figure 2. One-dimensional plot of (a) scientists/engineers and (b) researchers for mixed medium

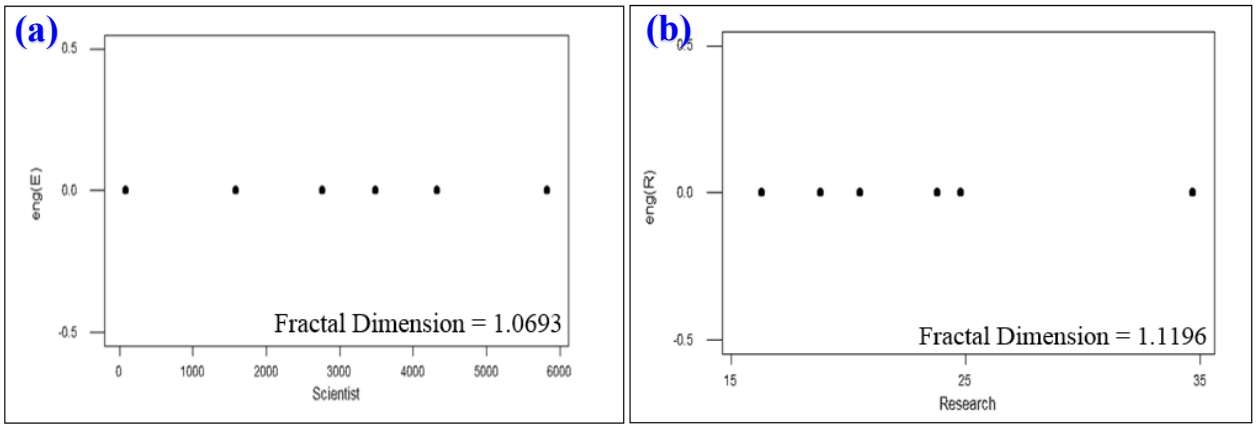

Figure 3. One-dimensional plot of (a) scientists/engineers and (b) researchers for english medium

Table 1. Summary of the fractal dimensions for the number of scientists/ engineers and researchers under various medium of instructions

Indicator	Medium of Instruction		
	Mother Tongue	Mixed	English
Engineers/Scientists	1.3362	1.2203	1.0693
Researchers	1.3760	1.1087	1.1196

In countries where the mother tongue is used as a medium of instruction, an average of about 33.62% roughness is induced on the production of scientists and engineers while about 37.60% variability is introduced in the production of researchers. In contrast, countries where the medium of instruction is English registered a mere 6.93% variability in the production of engineers and scientists and about 11% for researchers.

Most European and Asian countries used their respective mother tongues in universities and colleges while American and former British colonies used English. The levels of economic development of the European and Asian countries correspondingly varied significantly: some are economic giants while most of the other countries in this league are either underdeveloped or developing. We surmise that the medium of instruction may be a secondary reason for the observed high variability in the production of engineers and scientists in these countries. It is more likely that these numbers are influenced more by the economic development of the nations involved.

Supporting this conjecture are the cases of Japan and South Korea in Asia with high production of scientists and engineers per capita (and also highly developed as nations) using their mother tongues in schools and the contrasting cases of Myanmar and Laos with low production of engineers and scientists (and underdeveloped nations) also using their mother tongues. In both cases, the mother tongue is used as a medium of instruction, but the level of production of scientists and engineers are patently different. What appears to distinguish one set of countries from the other is their levels of national economic development.

A formal test of hypothesis to test the equality of the fractal dimensions of the three categories of nations produced an f-value of f = 14.8761 (P = 0.0002). This means that the variability in the production of engineers and scientists across the three different types of countries are statistically different beyond the 0.01 probability level.

5.0 Conclusions

The use of mother tongue as a medium of instruction induces greater variability in the production of both engineers/scientists and researchers for various countries across the globe. In contrast, the use of English as a medium of instruction induces uniformity in the production of this crucial manpower for national development. The rationale for the observed variability may be attributed to the varying levels of economic

development of countries employing their mother tongues in their universities and colleges.

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