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Research Paper

The production and distribution of scientific knowledge: A global perspective

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Abstract. The educational enterprise is not omnipotent and is heavily constrained by natural, socioeconomic and pedagogical factors. The present research aims to study the state of the production and distribution of scientific and mathematics knowledge worldwide using the Programme for International Student Assessment (PISA) 2018 big data bank. The first finding is that the distribution of this knowledge shows that about two-third of the world's population belongs to quality groups one, two, and three, representing the low-achieving section of the proficiency scale. The second finding is that there is practically no sign of domain specificity. Thus, the learning problems do not reside in the curriculum but in some higher cognitive factors such as general intelligence or developmental stage. It is high time to adopt educational policies oriented toward the real world rather than an aspired one.

Keywords: PISA 2018, scientific literacy, quality groups, proficiency distribution, educational efficiency, individual differences.

INTRODUCTION

During the last decade, the global educational enterprise has focused on producing and distributing scientific knowledge among the broad population. This effort is closely monitored and evaluated by international comparative studies led by the International Association for the Evaluation of Educational Achievement (IEA) and the Organization for Economic Co-operation and Development (OECD), leading to the creation of Big Data resources that allow for the robust first-time research related to the nature and efficiency of the global education enterprise.

IEA has conducted its metrics based on science and mathematics knowledge as defined by the national curricula (Mullis *et al*., 2020). OECD defined its metrics on an extended version of acquired science and mathematics termed “Knowledge skills” and understanding (Schleicher, 2018). However, the two variables are highly correlated. Yet reviewing research and the public discussion indicates that the terminology under discussion suffers from the “Babylon Syndrome” (Chen, 2022), which is a chaotic lack of common standardized terminology.

So, what does PISA really measure? The formal term used to describe the test results is “proficiency.” However, terms often used for the same variable are literacy, achievement, attainment, ability, skills, scores, outcomes, performance, and knowledge. Thus, the discussion concerning PISA results is entangled by the fact that educational sciences lack the universal standard that unifies the exact sciences (Wikipedia, 2022). This paper will refer to PISA’s definition that what is measured is an aggregate of scientific knowledge, skills and understanding. However, the complexity of the educational enterprise (5) requires an understanding of the current model that represents how knowledge, skills and under-

Table 1. Learning regulation terminology by three disciplines.

Behavioral Sciences	Psychology and NeuroSciences	Learning Sciences and Educational Sciences
Origin	Regulation systems	Outcomes
Innateness	G (general intelligence)	Declarative knowledge
Human genome	Executive function	Non-declarative knowledge
Modularity, cognitive toolkit	Innate principles	Cognitive skills

Table 2. The PISA scale of proficiency levels in math and science in all countries.

	Mathematics average proficiency (%)	Science average proficiency (%)
1	24	22
2	22	26
3	24	27
4	19	18
5	9	6
6	2	1

standing yield proficiency.

A summary of the current theoretical origins of learning regulation is described in Table 1.

Based on the best research in the disciplines, this terminology calls for the separation of three mechanisms that take place in the learning process that is not yet measured by international metrics.

Both PISA and Trends in International Mathematics and Science Study (TIMSS) have raised academic and public discussions that are concentrated on the ranking of the participating countries based on the average test results for each country. The public discussion focused mainly on the relationships between the education enterprise and economic returns. The theoretical framework developed by Bourdieu & Richardson, (1986) suggested that the educational enterprise is primarily responsible for the production of human capital, which is the workforce skills and knowledge accountable for the country's Gross Domestic Product (GDP). This social capital is the mastery of social codes that advance cooperation, status and development and the cultural capital, including tangible and symbolic goods. Recently, Hanushek and Woessmann (2012) coined the term "Knowledge capital" based on empirical research of twelve international studies that provided evidence for the major role of cognitive skills in the economic returns of education.

In the present paper, we want to search the following questions:

• What is the global distribution of scientific and mathematics knowledge among students?
• What are the present efficiency boundaries of the current educational enterprise?
• What can be done to enhance educational efficiency?
• What are the best educational policies that can be drawn from the study?

METHODOLOGY

The study used the big database of PISA 2018 and its ranking scale for science and mathematics proficiencies to answer the aforementioned questions (OECD, 2018).

RESULTS

The first results are presented in Table 2. The scale designed by OECD describes six levels of proficiency. Level 1 includes learners who still need to achieve the minimum proficiency as defined by international standards. Level 2 is the lowest proficiency required for enabling scientific literacy. Levels 3 and 4 include the average learners. Levels 5 and 6 represent the elite cohort of the population.

The quantitative distribution of the average yields of knowledge proficiency is quite disturbing. An average of 23% of the entire population stay under the minimal literacy requirement. Levels 1, 2, and 3, which include 72% of the world population in the participating countries, need to improve their efficiency of the universal educational enterprise. The elite intellectual share is only 1.5% of the population average. Levels 4, 5, and 6 are reached by 27.5% of the total population. The economic damage of the current situation was estimated to approach 731 trillion dollars (Hanushek and Woessmann, 2012). The social damage can only be guessed in terms of the division of the world into the first, second and third world. The cultural damage is getting the least attention from the public and the research circles, yet it should be seriously taken.

Figure 1 suggests practically no domain specificity between mathematics and science proficiencies. This finding justifies the assumption that it might be an innate system, such as the cognitive developmental stage

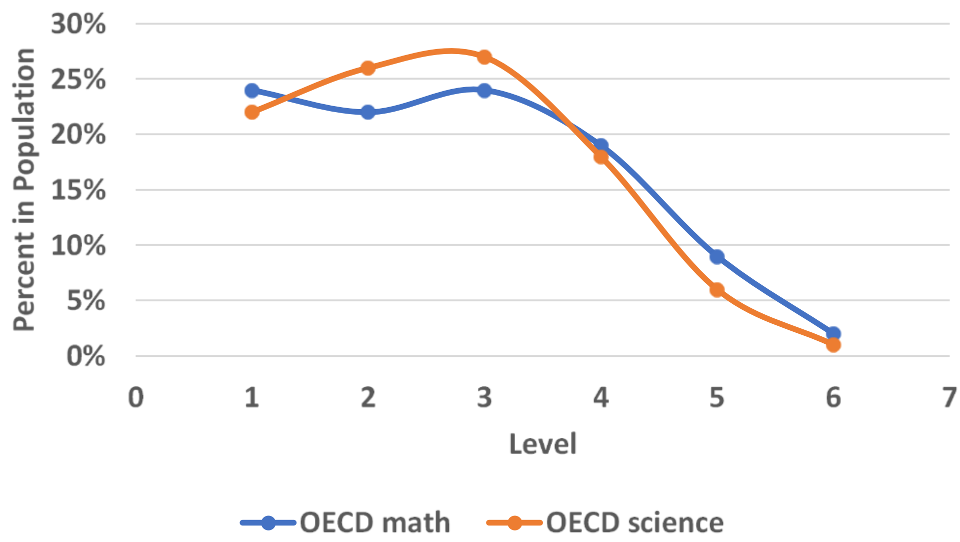

Figure 1. The universal distribution of math and science proficiency levels.

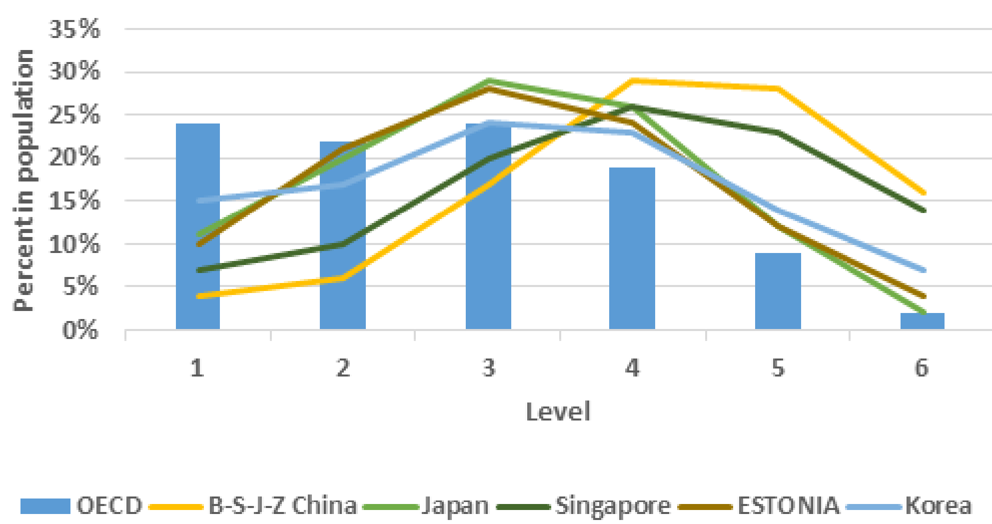

Figure 2. Distribution of mathematics proficiency in high-achieving countries.

(Galton, 1907) or general intelligence (Sunderman *et al*., 2005), that is regulating learning difficulties that such a large portion of the population is experiencing.

Figure 1 demonstrates a distribution curve based on the lower side of proficiency. Since human behavior should be distributed in a normal pattern, it might suggest the educational system's weakness is responsible for these inefficiencies and might be corrected if diagnosed more closely.

Boundaries of the educational enterprise

The current educational practice mixes facts with ideologies, and policies and practices seem to set goals without considering the existence of real boundaries, such as "No child left behind" (Hanushek and Woessmann, 2020), when in the real world more than seventy percent are left behind. At the same time, the focus of educational research on the average ignores the nature of individual differences and human diversities responsible for the universal normal distribution of human characteristics.

In Figures 2 and 3, the study presents the distribution of science and mathematics proficiencies in five countries that achieved the highest ranking. The figures show the average levels per section in the background to enable comparison. The major finding is that the distribution of proficiency, unlike the world average, takes the pattern of a normal curve. The individual differences and diversity are expressed in Galton's metrics, enabling the systems'

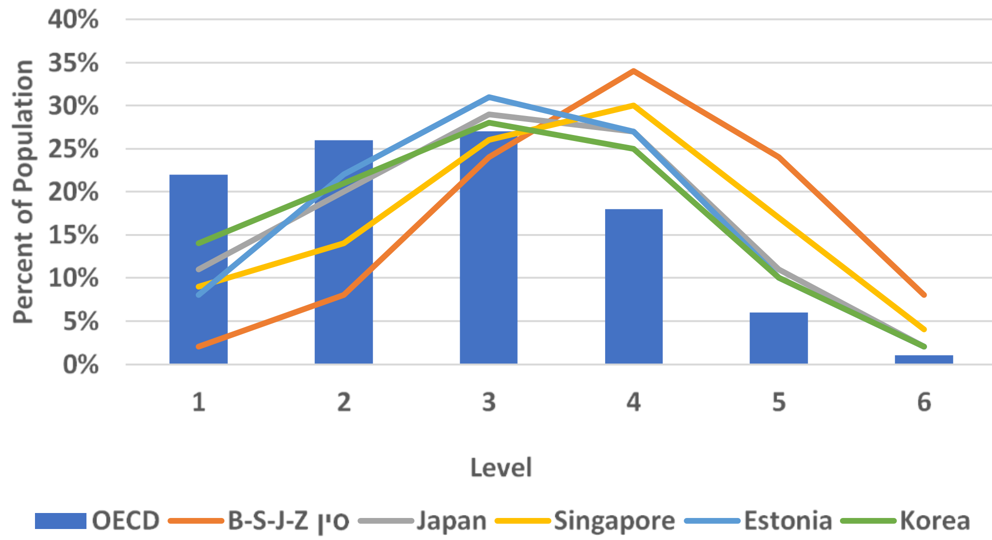

Figure 3. Distribution of science proficiency in high-achieving countries.

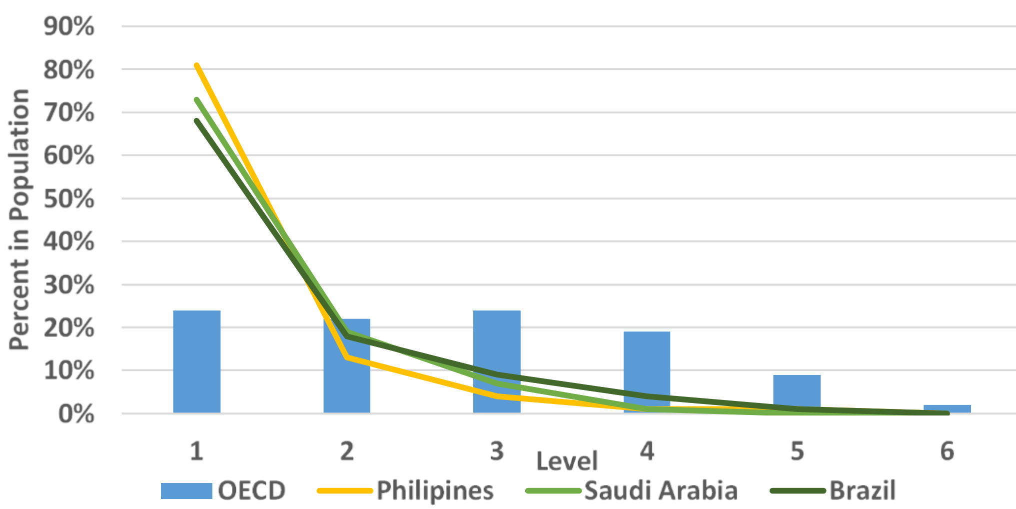

Figure 4. Distribution of mathematics proficiency levels among low-achieving countries.

efficiency to reduce the percentage of low achievers (Levels 1+2) from 48% to 24.4%. It must be understood that even the best educational systems using the present teaching and learning strategies cannot cope with about 25% of the population. On the other hand, the cohort of level 6, which is the highest efficiency currently possible, marks the efficiency limits of the best educational systems. The pessimistic perspective masked by focusing on the average dimensions is affected by the state of the low-achieving countries. In Figures 4 and 5, the distribution levels of five of these countries are presented. As evident, the mastery of knowledge at levels 5 and 6 is zero. These countries produce practically no qualitative elite at all. The middle-range level portion of the population is only 12.6%. 91% of the people maintain knowledge at levels 1 and 2, which are the lowest section of the proficiency levels; however, its dark impact on the social, economic and cultural capital does not find its appropriate place beyond political statements such as "Every child can," "EFA, education for all" or "no child left behind." From the PISA set of data, too many children are left behind. In all countries studied by PISA so far, at least 24% of the population is unfortunately left behind.

Tables 3 and 4 show that in cohorts 5+6 in the higher achieving countries, the average proficiency is 22% compared to 0% in the low achieving countries. This number sets the potential of the educational systems' effeteness between the boundaries of 24% of the population that will be "left behind," and 76% are unable to get to the top 5 and 6 cohorts. Yet the good news is that at least 46% of the population can be advanced significantly, provided policies, innovation, resources and sound

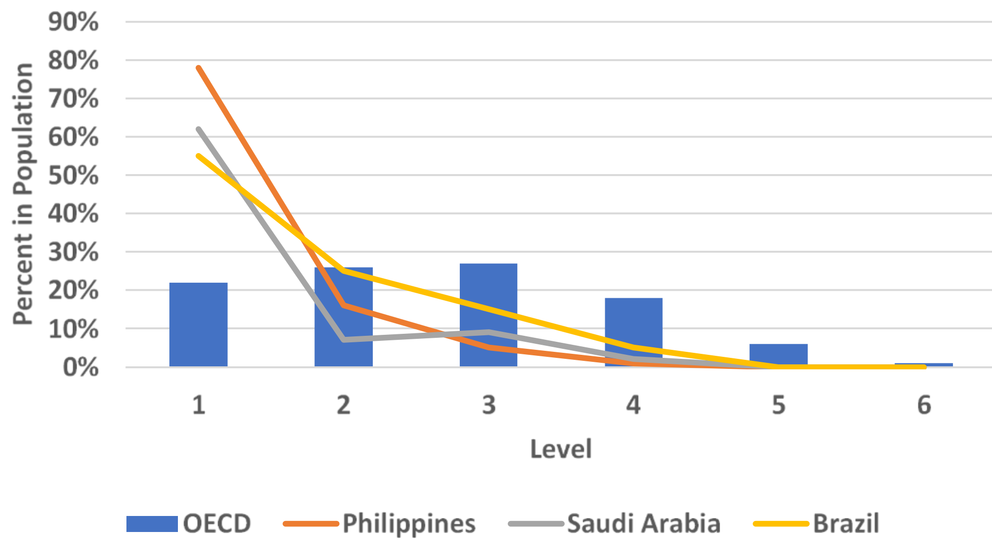

Figure 5. Distribution of science proficiency levels in low-achieving countries.

Table 3. Average of high and low-achievement countries in mathematics.

Levels	OECD (%)	Avg 1 (%) High-achieving countries	Avg 2 (%) Low-achieving countries
1	24	9	**72**
2	22	15	**17**
3	24	24	**8**
4	19	25	**3**
5	9	18	**0**
6	2	9	**0**

Table 4. Average of high and low achievement countries in science.

Levels	OECD (%)	Avg 1 (%) High-achieving countries	Avg 2 (%) Low-achieving countries
1	22	9	**64**
2	26	17	**20**
3	27	28	**10**
4	18	29	**3**
5	6	14	**0**
6	1	4	**0**

theories and concepts are available. In economic returns only, the human capital that can respond to an advanced educational action is worth 365 trillion dollars.

DISCUSSION

The big database assembled by OECD's PISA 2018 study has provided a remarkable and reliable source for learning analytics and universal perspectives of the education enterprise worldwide. Analyzing the distribution of the six quality level groups rather than a linear grading of an average proficiency between countries enabled us to develop a new perspective more sensitive to the state of education worldwide.

The global perspective of the production and distribution of science and math proficiency presented in Figure 1 shows the dark side of educational enterprise efficiency. 23% of the world population still needs to attain the minimal requirement of scientific proficiency. Hanushek and Woessmann (2020) estimated the price of the inefficiency in producing human capital to be 731 trillion

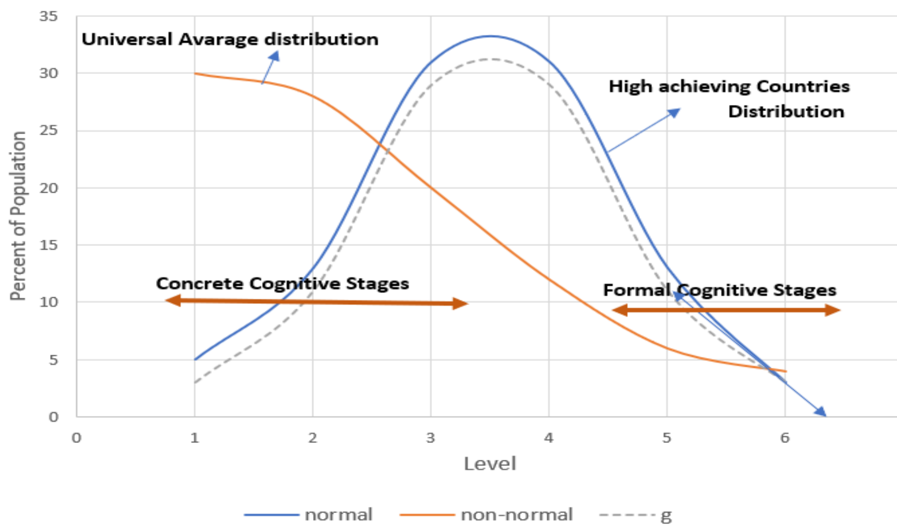

Figure 6. Theoretical summary of the study.

Dollars. The damage to the social and cultural capital was not closely studied, but will later evaluate these aspects by comparing first and third-world countries.

Figure 1 provides another interpretation regarding the overall distribution of proficiency for both math and science. The almost similar pattern of the two disciplines suggests that there is no domain specificity pertaining to math and science. The best explanation for this is that some higher universal cognitive factor must regulate learning efficiency. Possible candidates for such a role can be either general intelligence which fits the regulation of proficiency rather than the modular domain dependent learning, or the developmental cognitive stage acquired (Galton, 1907). The next question that follows is how come the distribution of proficiency does not attain a normal curve as most human behaviors do? (Sunderman *et al.*, 2005). A comparison of the distribution pattern between high and low-achieving countries suggests that the distortion from the normal curve is caused by the high rate of failure by the low-achieving countries.

It is difficult to isolate a major factor responsible for the disastrous failure in many countries. The educational enterprise is a highly complex system. According to Hattie (2015), 252 variables contribute to schooling efficiency. Thus, it is probably many candidates that are affecting the poor outcomes such as low income, insufficient resources, bad pedagogical practices, the low literacy level of the family and low expectations due to unemployment.

Boundaries of the educational enterprise: What schools can and cannot do?

Current educational policies and practices were established during the industrial revolution and, to this very day, are still based on a mechanical perception of learning and schooling (Papa *et al.*, 2021). Behaviorism is still dominant within the educational theory, thus OECD in its vision "learning framework for 2030" backed by more than 170 academic experts has defined 23 skills or competencies required for building literacy and numeracy that are needed to engage with the present world (Schleicher, 2018). The OECD document states, "These transformative competencies are developmental in nature and thus learnable". The statement that all competencies can be learned is at the heart of the general belief that education is omnipotent and there are no boundaries to educational efficiency. The current study shows that this kind of policy ignores the real world's state.

Pinker (2003), in his book The Blank Slate criticized social science for ignoring the extended model for learning and cognition based on Behavioral Genetics, Neuro-Science and Cognitive Psychology (Pinker, 2003). Unfortunately, Educational Sciences are still using the Blank Slate concept as a model for learning and behavior. They cannot define research-based policies to cope with the inefficiencies of schooling demonstrated by the PISA study.

Using the proficiency distribution scale of five high-achieving countries (Tables 3 and 4), the average outcomes can be used as a quantitative measure of the optimal efficiency of the educational enterprise. Figure 6 tells us the following:

The distribution curve assumes a normal pattern as expected from individual differences in human behavior (Sunderman *et al.*, 2005). The results display the optimal efficiency that can be attained at present.

Under optimal conditions, 9.1% of the population is still left behind. Levels 1 and 2, representing the lowest section of the population, amount to 23.1%. This represents the lowest boundary possible at present.

Under these optimal conditions, the share of the intellectual elite that can be achieved is 3.6%. Combining levels 5 and 6 yields 18%. This is the best efficiency; the best educational systems can achieve. Therefore, the current study suggests that the optimal efficiency extends between 18% of the population as the highest boundary and 23.1% as the lowest. These are the realistic expectations that can be drawn from real-world data. Thus, Figure 6 suggests the conclusions from the present study.

CONCLUSION

The high-achieving countries present the optimal efficiency in producing scientific and mathematical knowledge in the broad population. The distribution of proficiency levels attains a normal curve analog to any other human behavior attributes. This result reflects the best that can be done by the present educational state of the art, confronting the boundaries set by intrinsic factors regulating individual differences in learning proficiency (such as concrete or formal thinking or general intelligence). Educational policymakers should set realistic objectives within the best possible boundaries rather than make misleading statements such as no child left behind, closing the gap, or everyone can study math.

On the other hand, the fact that the low-achieving countries display a huge gap from normal distribution suggests an educational policy that aspires to reduce the quality groups at levels 1, 2 and 3 by seeking to achieve a normal distribution. This highly realistic goal will require mobilizing resources toward the low-achieving populations. These resources should include budgets, specific pedagogies, innovative technologies and curricular adaptations. However, this aspect requires further study beyond the present one.

DECLARATIONS

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Author contributions: All authors have contributed to writing, designing, compiling and editing the final manuscript.

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