

# Human Capital Foundations for the Building of Science and Math Disciplines

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## **ABSTRACT**

This paper describes the status of developing human capital foundations for the building of science and math disciplines in the Philippines. At the moment, the country lacks the strategies to establish the roots of the science and math disciplines. This paper discusses the need to build a stream of talent to form strong healthy roots and build a culture of science and mathematics, by strengthening the fundamentals for science and math at the grade school and high school levels. A healthy foundation could help in developing and retaining more PhD holders who will teach and conduct researches in the country and train more students to undertake advanced degrees. The paper also cites good practices and examples currently done to improve science and math education. Internal factors such as developing interest in the young, providing incentives especially for high school math and science teachers, and establishing a critical mass of professionals; and external factors such as government support and cultivating a culture of math and science excellence, can improve the human capital for science and math education in the country.

## **Keywords:**

human capital foundations, critical mass, cultivating math and science excellence

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## **INTRODUCTION**

Science and math education is important for Philippine economic development. However, when one looks at our present state of graduate education and scientific research, one sees lack of strategies to establish the roots of these disciplines. As a country, we assume the existence of the **organizational and or institutional infrastructure** (funding, mentoring, time, etc.) or that this is the job of the Department of Science and Technology (DOST) or the university in general.

My experience together with many colleagues from different universities is that this infrastructure still has to be built and the only ones who can do it are academics who are passionate about developing science and mathematics and are willing to make sacrifices to do so.

I have described this effort as that of building a school of mathematics or science, rather than simply promoting mathematics research and publication. The research and publications are products of

the school, like the fruit on a tree. But it is the tree that we need to attend to. Thus, we need to plant and tend this tree so that it will have many strong and healthy roots.

E. F. Schumacher in his book, “Small is Beautiful: Economics as if People Really Mattered,” has an eloquent passage about the transplanting, not of mathematics, but of a great refinery: the evolution of this refinery from something simple—

*“Then this was added and that was modified, and so the whole thing became more and more complex. But even more, this complex establishment is but the tip of an iceberg. We cannot see the immensity and complexity of the arrangements that allow crude oil to flow into the refinery and ensure that a multitude of consignments of refined products. . . reaches innumerable consumers through a most elaborate distribution system. Nor can we see the intellectual achievements behind the planning, the organizing, the financing and marketing. Least of all can we see the great educational background which is the precondition of all, extending from primary schools to universities and specialized research establishments . . . the visitor sees only the tip of the iceberg: there is ten times as much somewhere else, which he cannot see, and without the “ten,” the “one” is worthless. And if the “ten” is not supplied by the country or society in which the refinery has been erected, either the refinery simply does not work or it is, in fact, a foreign body depending for most of its life on some other society” (Schumacher 1975).*

I have sometimes remarked that, due to the absence of the deeper infrastructure,

our scientific enterprise is a tree with a weak base or weak roots. Philippine science actually has its roots and continuing nourishment, not from our country, but from departments and laboratories elsewhere in the world.

A fundamental problem to the task of building an intellectual tradition is to be aware of the rest of the organizational and institutional infrastructure that is a condition of possibility of the great intellectual centers of the world. A school of research requires at least as much societal infrastructure as Schumacher’s factory. Unless we are aware of this need and try to identify and build such infrastructure, our intellectual house will be built on shifting sand.

## LOOKING FORWARD

The major bottleneck to our moving forward in scientific research, at least on the mathematics and natural science levels (which I know best), but probably also in other scientific and technological fields, is **NUMBERS. We simply do not have enough high-level mathematicians and scientists.**

As example, the Philippines-California Advanced Research Institutes (PCARI) do not get enough high-level research proposals. And the research proponents are actually leading a few other research projects.

In the Engineering Research and Development for Technology (ERDT) and Commission on Higher Education (CHED) Faculty Development Program, there are actually more funds than applicants.

Some may say that this is because the funds are not big enough. Yes, they can be bigger. But the reality is that if equivalent funds were offered to our colleagues in Vietnam or Indonesia, there would be more takers. It is also lack of interest and culture.

### **WE NEED TO BUILD PHD PROGRAMS AND RESEARCH IN MORE UNIVERSITIES**

We have very few Universities with departments that have good PhD programs in Mathematics and the Natural Sciences. In mathematics, there are basically the same departments that emerged in the Consortium and Engineering and Science Education Program (ESEP) period, which was 20-35 years ago.

One reason for giving a lot of details on our early work in developing mathematics, physics and chemistry PhDs is to highlight the leadership role that academics must play to make these things happen. I hope that re-telling our story may encourage more to establish these programs. Funding from CHED and the Department of Science and Technology (DOST) is actually more available today. Our experience is that what succeeds are groups of scientists, with long-term commitment and who grow in friendship and shared purpose.

### **RECONSIDERING REASONS**

But our challenges go deeper than seeking to have more university PhD and research programs.

Our usual analysis is that our lack of scientific manpower is due to lack of government funding. We cite Vietnam, which we are told sent 2,000 for PhD

studies abroad recently. We ask why does our government not do the same. One answer is that most scholars would probably not come back. But a reason we do not often discuss is that, if our government gave us that money, we would not find 2,000 who would be interested and would qualify for high level PhDs abroad.

One of the reasons why Vietnam could do this is that it has a very large number of young people who qualify for high level PhDs abroad. We may cite the recent articles on the performance of Vietnamese high school students in the most demanding international comparative assessment study PISA, or the Programme for International Student Assessment.

Further, the Bangkok Post in April 2015 wrote:

*Vietnam's performance in the latest round of the PISA has created a stir among education experts and policymakers around the world.*

*The country's 15-year olds participated for the first time in the 2012 assessment and ranked 17<sup>th</sup> in mathematics, 8<sup>th</sup> in science, and 19<sup>th</sup> in reading among 65 participating nations, placing Vietnam above the OECD average. At a time when Western countries are striving to replicate East Asia's success in education, Vietnam has outranked the United States, Australia, and the United Kingdom. In doing so, it has become an exception to the argument that educational excellence is not possible without a high level of economic development.*

Our performance in Trends in International Mathematics and Science Study (TIMSS) has been so poor, that we do not even try PISA.

So I go back to my analysis in the 1970s that there are two major drivers to building up scientific and technological capability: the force of talent and genius and the support of society.

We always tend to look to the lack of support from society. But we do not study enough the lack of interest and talent at the university level.

### **BUILDING THE NEEDED STREAM OF TALENT FROM GRADE SCHOOL AND HIGH SCHOOL: BUILDING A CULTURE OF SCIENCE AND MATHEMATICS**

#### ***Problem-Solving***

Let me begin with work I am involved in to identify and develop such talent and genius at the grade school and high school level.

The major challenge in developing future mathematicians and scientists at the grade school and high school levels is not so much lack of high level courses, but lack of fundamentals. For mathematics, fundamentals mean doing real problem-solving.

What is the difference between exercises and problems? A book we use to give students the experience of real problem-solving says:

*“An **exercise** is a question that tests a student’s mastery of a narrowly focused technique, usually one that was recently “covered.” Exercises may be hard or easy, but they are never puzzling, for it is immediately clear how to proceed. . . . In contrast, a **problem** is a question that cannot be answered immediately. Problems are often open-ended, paradoxical and*

*sometimes unsolvable, and require investigation before one can come close to a solution. Problems and problem-solving are at the heart of mathematics.”* (Zeitiz 2007).

We usually give exercises, meaning problems that can be solved using techniques we have taught. Real problems are those where we do not know what to do— we have to try several things, experiment, make mistakes— and usually they take hours or days.

In the sciences it is the difference between demonstrations and experiments. We usually do demonstrations. Experiments, like problems in math, demand trying various approaches, making mistakes and taking a lot of time.

#### **The Ateneo de Manila Experience**

Dr. Queena Lee-Chua and I started a Summer Problem-Solving Seminar with Freshman and Sophomore Ateneo College students over 10 years ago. There is an excellent book, Zeitiz’s “The Art and Craft of Problem-Solving” (2007), which we have been using.

We then get the students who have taken this course to coach Ateneo Grade School and High School (HS) students. And over the years they have developed a collection of challenging problems, which can be used at grade school and high school levels.

Ateneo de Manila High School mathematics faculty also do Saturday tutorials for promising grade school pupils in some Quezon City public schools and we have identified some wonderful talent and placed them in Philippine Science HS, Ateneo de Manila HS and other good high schools. More effort is needed to identify

and develop these talents. Otherwise, the country will lose them.

This culture of problem-solving is highly developed in Eastern Europe, China, Vietnam. I was impressed to find out that all through the wars Vietnam had with France and the US, they continued Math Olympiads at the village, town, province levels. It is no surprise that they have been producing some of the best mathematicians in the world.

### ***Developing a Group of Teachers for Problem-Solving***

It would be wonderful if we could develop a cadre of high school mathematics teachers who could be teachers and coaches for problem-solving. To get there, we have to help teachers overcome the fear of not knowing how to solve a problem. I tell them that I sometimes go through problems in our summer class, where I do not know how to solve them either. Sometimes we eventually solve the problem during that summer. Sometimes we do not and maybe we might solve it with the class the next summer. The important thing is to have the experience of real problem-solving.

The greatest pleasure is when a student solves a problem I do not know how to solve or comes out with an amazingly elegant solution. Then I know I have made progress in identifying talent.

### ***A Proposal for Identifying and Developing Mathematics Talent at Grade School and High School***

I suggest that mathematics departments consider running similar problem-solving courses for college students and extend the problem-solving to a high school and grade school near them.

We can then aim to bring these efforts into a network and as what Romania does, that is, it posts a problem of the week online and everyone can join and post solutions.

### ***In other Fields as well***

Several computer science departments in the country already participate in international programming competitions. They can bring these competitions down to the high school level. In general, these programming competitions require good mathematics and physics capabilities and there are usually math and physics majors on the teams.

There are also modeling competitions, where talent in other sciences and engineering can be developed.

I believe there are similar efforts at developing talent in physics and chemistry. But I have to leave the proposals to those in these disciplines.

The main point about these initiatives is to develop a culture that is comfortable facing unknown problems and working with them over long periods of time. Also to develop teachers who are comfortable not knowing the answers either and are happy to find that a pupil in front of them is actually smarter.

This is the **culture of science and mathematics**. It is a culture we need to develop from grade school and high school years if we are to identify and develop a greater number of talents for the future.

We can then turn to DOST, CHED, etc. to provide the funds for further studies and research for this new talent pool.

### **Support from Society**

As I said in the beginning we tend to focus on support for the leaves and the fruits of our S&T tree— PhDs, research, publications, technologies, and innovations.

We need to look as well and care for the roots and the trunk— the identification and development of a stream of talent from grade school, high school on.

This will not happen without determined effort. Philippine culture in general puts high value on learning English well (I think that sometimes we value fluency even if the quality of thought is not particularly good). We are rather accepting of weakness in mathematics and science. We can see this in the great attention given to Law and the Bar exams.

So we need to build a structure that will:

- 1) Identify talent at least by intermediate grades (5 & 6) and through high school.
- 2) Include mathematics problem-solving for them.
- 3) Include experiments in the natural sciences for them.
- 4) Inspire them to pursue science and engineering in university.

What will this structure require?

- 1) A cadre of teachers who will make it a mission to carry out 1 to 4 above.
- 2) A career path for these teachers with recognition and reward.

If one looks at the biography of great scientists, almost all trace their “vocation” to science to a high school teacher. These are the foundations of a scientific culture for our country.

### **FORCE OF TALENT/ GENIUS AND SUPPORT OF SOCIETY**

We ask, then, what is this infrastructure? We may divide it into two parts: internal and external. Parts of the internal infrastructure are: first, talent or genius: the development and growth of any serious discipline always depends to a large extent on the force of genius of a few; second, inspiring teachers: most of us owe our intellectual “vocation” to an inspiring teacher in school; third, a “critical mass” of scholars: a stable scholarly tradition can only grow from a school of thought; and finally, continuing contact with scholars throughout the world.

Of the external infrastructure we may mention first, society’s support for high quality education in terms of sufficient rewards for teachers and identification and support of talent and genius; in addition, clear career opportunities (with commensurate professional rewards) for scholars and teachers; and lastly, the general value that society puts on an intellectual career.

How can this infrastructure be developed?

In part, at least, **this infrastructure can be developed through organization, through the identification and nurturing of talent, through efforts at visibility and influence on decision makers, through the general upgrading of education.**

### **CLOSING REMARKS**

Developing human capital in the mathematics and science education in the

Philippines is a challenge due to lack of interest among the young, lack of incentives to the teachers and passionate academics who can build the science infrastructure, and lack of support by society. These make the Philippines uncompetitive among the ASEAN neighbors. In contrast, Vietnam has done well in cultivating this branch of knowledge because it has the culture of excellence in science and mathematics and because government has provided opportunities for the profession to flourish and grow.

The Philippines need to review its strategies to improve on the human capital for science and math education. There are internal factors such as developing interest in the young and identifying where these geniuses are, providing incentives especially for high school math and science teachers

and establishing a critical mass of professionals who will be passionate enough to build the necessary academic infrastructure. External factors to the development of human capital in science and math are government support and cultivating a culture of math and science excellence.

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