PAASE Recommendations on S&T Human Capital Development*

Carlos Primo C. David[1], Gisela P. Padilla-Concepcion[2], Ernesto M. Pernia[3**], Sarah Lynne S. Daway-Ducanes[3], Alfredo E. Pascual[4***], and Bienvenido F. Nebres, S.J.[5****]

[1]National Institute of Geological Sciences, College of Science, University of the Philippines Diliman
[2]The Marine Science Institute, College of Science, University of the Philippines Diliman
[3]School of Economics, University of the Philippines Diliman
[4]Institute of Corporate Directors, Makati City, Philippines
[5]Department of Mathematics, Ateneo de Manila University, Quezon City, Philippines

Research shows that the size of a nation's science and technology (S&T) labor force and training system have a positive effect on economic development (Schofer et al., 2000). Specifically, a highly skilled S&T workforce is considered one of four pillars required to transform into a knowledge-based economy (ADB, 2007). And within the last decade or so, there is a resurgence of efforts of various countries, including the Philippines, to quantify the contributions of its S&T workforce in creating a positive impact in society towards nation building (DOST, 2019).

This paper deals with the Philippines' S&T human capital development (HCD) situation. It draws on the recent series of evidence-based email discussions and webinars facilitated by the Philippine American Academy of Science and Engineering (PAASE) and related research findings and supporting data. The paper aims to present a factual assessment of the S&T HCD situation, offer recommendations for improvements to the concerned government agencies, and propose strategies by which PAASE can help meet our country's S&T human capital needs.

CURRENT SITUATION

This section addresses three questions pertinent to the quality and supply-demand scenario of S&T workers and provides the context for our intended goals and strategies.

Does the country lack S&T graduates? Data indicate we have sufficient Bachelors of Science (BS) graduates to satisfy the local needs, but not enough Masters (MS), PhDs, and postdoctoral fellows to serve as high-skill researchers in academe, industry, and government. Many of our higher education institutions (HEIs), including state universities and colleges (SUCs), need well-qualified S&T faculty to undertake innovative research that supports the R&D needs of the country. This includes producing a growing breed of researchers who can sustain innovation required by various industries. We also lack formal training programs for preparing competent technical (or tech-voc) workers for companies in the growing technology industry. Our capacity to produce highly skilled researchers and proficient tech-voc workers is critical in building an innovation ecosystem that can spur industrial development on the back of our national endowments – rich natural resources and a large pool of human resources.

The percentage of S&T college graduates in 2016 is at 28.7%, comparable to Korea (29.9%) and Singapore (34.5%) and even slightly higher compared to Thailand and Vietnam (Paqueo et al., 2019 in Padolina, 2020). The same finding is reported by USAID STRIDE (2014), which concludes that the supply of S&T graduates continues to exceed local demand, resulting in out-migration of engineers abroad, where there are better employment opportunities for S&T graduates.

Information is lacking about S&T postgraduates (MS, PhDs, and postdocs). Still, several pieces of evidence indicate that the supply of S&T workers with postgraduate degrees is unable to

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** Secretary, National Economic and Development Authority, Republic of the Philippines, 2016-2020
*** President, University of the Philippines, 2011-2017
**** President, Ateneo de Manila University, 1993-2011

meet market demand (PIDS, 2019): (1) S&T workers at higher positions in government (requiring advanced studies) are not being filled, including senior engineers in DPWH and medical specialists in DOH; (2) the academic requirements for higher positions in government are continually being waived or downgraded to be filled; (3) Researchers in the Department of

[1] The Philippine numbers are well below ASEAN comparators (CHED, 2018 in Padolina, 2020).

The country can be made a more attractive production site for foreign (and domestic) producers in the global technology supply chain and a venue for outsourcing high-value support services of international companies. For this, we need to develop a technically proficient workforce consisting of sophisticated equipment operators, skilled laboratory technicians, scientific information transcriptionists, digital data processors, and the like, who can be employed in these operations – both here and abroad.

Is the demand for S&T graduates increasing? Yes, there appears to be a general shortage of S&T graduates for most fields to meet current local and overseas demand. Another relevant question would be whether or not this excess demand for (or lack of supply of) S&T graduates would persist in the future, as this would require meticulous medium- and long-term planning.

S&T workers constitute only 4.9% of the total labor force of the country -- broken down into Engineering (2.8%), Computing/IT (1.9%), Life Sciences (0.1%), Math and Statistics (0.06%), and Physical Sciences (0.04%) (PIDS, 2019). STRIDE (2014) not only accurately points out the stagnant recruitment of the government and SUCs for S&T graduates, but more importantly casts a spotlight on the low demand coming from industry, which should be the biggest and most dynamic employer of S&T graduates in emerging economies. The number of researchers per million population is quite telling in terms of how far we are behind our ASEAN neighbors (Table 1). Finally, while the employment of current S&T graduates is not an issue *per se*, with 87% of S&T graduates reporting that they are gainfully employed and exceeding the national employment average of 71% (PIDS, 2019), there remains the issue of whether or not S&T graduates are employed in jobs that adequately utilize their acquired educational training and skills.

Variations in labor market conditions exist across the different S&T fields for both supply of and demand for S&T workers with a general trend of increasing demand for such expertise is expected in the future (PIDS, 2019). The same study predicts a potential domestic excess supply of Computing/IT professionals and excess demand for workers in other S&T fields. The most considerable excess demand (or supply deficit) is anticipated for Engineering graduates. The projected excess demand (or supply deficit) is smaller for Math/Statistics, Life Sciences, and Physical Sciences graduates. While the current excess/deficit demand indicators for Math/Statistics and other Science fields are relatively small, any technology-driven industry growth (e.g., more widespread use of big data analytics even in government) can instantaneously raise the demand for researchers or workers in these fields. This likely event has to be scrupulously planned to enable supply to catch up with minimal disruptions to industry and society, in general.

Furthermore, it should be noted that many S&T graduates tend to land jobs for which their education and skills either exceed the requirements or are not a perfect match for their job requirements, possibly contributing to underemployment among

Science and Technology (DOST) Research and Development (R&D) Institutes have a sub-optimal composition with only 27% and 4% of the workforce having MS and PhD, respectively; and, (4) SUCs and HEIs have an average faculty profile still dominated by BS graduates (46%), with MS (40%) and PhD (14%) graduates completing the roster.

these S&T workers. Data from a tracer study of one of the largest technical universities in Metro Manila show that 19-24% of their engineering graduates are employed in industries not likely requiring engineering skills, including in business process outsourcing and real estate renting/sales (Unpublished report, 2019). The same is observed in government agencies where certain positions requiring specialized S&T graduates are instead employing engineering graduates. Examples are engineers employed as physical and life science research specialists in DOST and as statisticians in the Philippine Statistics Authority (PIDS, 2019).

Lastly, the demand for S&T graduates is very low, coming from local industries (STRIDE, 2014). Since R&D is not widely seen as a critical aspect of maintaining industry competitiveness, the few S&T workers employed in industries are primarily relegated to production, manufacturing, and even sales and marketing activities.

Is the country's S&T education at par with other ASEAN countries? Certain pieces of evidence suggest that it is not.

In the most recent Trends in International Mathematics and Science Study (TIMSS), the Philippines ranked last in 58 countries in the Grade 4 science and math assessment. The same dismal record was observed when the country last participated in TIMSS in 2003. Similarly, in the Programme for International Student Assessment (PISA) (2018) study involving 15-year-old students, the Philippines ranked second lowest for both Science and Math subjects out of the 79 countries that participated. These results may reflect the low levels of comprehension in Math and Science among students in the regional public school system, from where most test-takers come.

However, it should be noted that there are city-based and regional science high schools, including those under the Philippine Science High School system (>1,000 graduates in 2019) and LGU-supported schools with better S&T programs likely at par with our ASEAN counterparts. The evidence can be seen in the strong performance of students from these local schools in regional and international Math and Science competitions. The same students can also compete for admission to highly reputed universities in Metro Manila, where the entrance exams are primarily based on proficiency in reading comprehension in English, Math, and Science. Aside from the need to redress the problems of relatively high poverty incidence and wide inequality across the regions, there is also a clear case for a nationwide strengthening of basic education, which feeds our tertiary education institutions. Still, it is worth noting that foreign companies commend Filipino technical workers (mainly engineers) as highly trainable employees with a strong educational background (STRIDE, 2014).

DEFINING THE GOALS

The country's S&T workforce development is a complex systemic problem with many compounding internal and external issues affecting quality and supply-demand dynamics. Solving the problem on all fronts will require a coordinated and concerted effort from various sectors, including synergistic

[1] A major conclusion of STRIDE (2014) involves the lack of postdoctoral training.

Table 1: UNESCO data for year 2016-2017.

Country	# researchers per million population	% employment in Industry	% employment in Universities	% employment in Government
Singapore	7,637.0	47.8	44.8	7.4
Malaysia	3,537.8	17.6	71.6	10.8
Thailand	1,990.0	40.5	48.2	10.6
Vietnam	1,414.0	16.9	50.7	31.8
Indonesia	540.2	2.6	90.5	6.9
Philippines	198.2	32.9	52.2	13.0
Cambodia	51.2	4.3	40.6	41.9
Myanmar	30.3	0	34.2	65.8
Laos	ND			

public-private partnerships. Thus, a more focused approach addressing key concerns should be undertaken. Moreover, a central theme in the recommended goals and strategies is strengthening regional development for human capital development and enhancement. To further focus PAASE's efforts as an organization, it is proposed that we first concentrate on two to three regions and create sustainable pockets of excellence. Lastly, these focused interventions must have tangible indicators that can be measured to track the intended goals' progress.

1. **Improving Science, Technology, Engineering, and Mathematics (STEM) education at the Secondary Level**

   The improvement of STEM instruction at the secondary level is deemed most critical not only in terms of preparing students for tertiary education, but actually convincing them to enter STEM courses in college. Even at the primary level, our country already ranks at the bottom (TIMSS results for 4th Graders in 2019). An immense impact may be realized when intervention is initially done in the four years of Junior High School and the STEM track in Senior High School, where regular natural science subjects (Earth Science, Biology, Physics, and Chemistry) are formally taught. Such an approach should result in more interest in STEM programs in the two-year Senior High School curriculum and eventually enrollment in STEM courses at the tertiary level. Of course, it may very well be that our educational system is behind not just in science and math but in all other major subjects. Therefore, a long-term assessment of the whole education life cycle ecosystem is warranted.

   It is at the high school level, where subject expertise is already required in teachers – a crucial factor, which the current public school system desperately lacks. The numerous teacher training workshops in Math and Science also seem insufficient to improve STEM instruction significantly. Week-long workshops cannot solve the lack of foundational skills among STEM public HS teachers. Addressing the shortcomings requires a more holistic intervention strategy, which will be discussed at length below.

2. **Increasing PhD faculty in SUCs and other HEIs to increase research productivity**

   As stated above, STEM instruction at the Tertiary level may be further improved by increasing the number of MS and PhD degree holders in the SUC and HEI faculty roster. Another foreseen positive effect of this is the increase in the support for research activities in SUCs and HEIs and even the establishment of quality postgraduate programs. A critical mass of PhDs (> 3) in each department is the intended goal, as this will result in the synergistic sharing of teaching loads, research collaboration, and resource pooling. SUC and HEI programs on the verge of breaching this critical mass and showing early-stage research efforts need to be identified and targeted for appropriate support.

   Two issues need to be addressed: encouragement of existing or new PhDs to take faculty positions in regional SUCs, besides the overall increase in the country's production rate of PhDs. Both issues need to be systematically tackled by the national government with the active cooperation of S&T organizations, such as PAASE.

3. **Strengthening the innovation environment for increased industry collaboration and tech startup promotion**

   The main aim of S&T HCD is to increase the employment opportunities of S&T graduates by increasing industry absorption and through the promotion of technopreneurship. R&D driven by industry requirements can be a catalyst, not only for more employment and better matching of skills among S&T graduates in existing companies, but also for the creation of businesses requiring high intellectual capital, which may be the engine for generating more employment among S&T graduates in the future. Such R&D-driven industry growth may also attract S&T graduates from both here and abroad to work in the country.

STRATEGIES

Ten concrete strategies are recommended to achieve the three goals outlined above. Along with these strategies, the systematic collection of S&T data should be institutionalized so that more accurate information for analyses and tracking of metrics related to S&T HCD can be made moving forward.

1. **Improving STEM education at the Secondary Level**

   Strategies for improving STEM education at the secondary level will be two-pronged: one for the general public school system and specifically for science high schools. It should be noted that the recommended approaches do not address the root problem of STEM teacher quality, whose improvement should remain a long-term goal of the country. As part of the short- to medium-term plan – for the general public school system, the following are the recommended interventions:

   - **Encourage public schools to use pre-prepared worksheet-based materials**, such as the Learning

Activity Sheets of the Dynamic Learning Program (DLP) of the Central Visayan Institute and Foundation, which fosters critical thinking and independent study (Bernido and Bernido, 2020). To provide other supplementary instructional materials, PAASE members can be tapped to develop curated learning materials already available on the internet.

- **Organize science and math-related activities such as quiz bees**. Arguably more important than the prestige of qualifying and even winning in a national quiz bee or international competition is the preparatory aspect for such contests – a consideration which is not currently given due emphasis. A module-based preparatory kit can thus be developed and distributed to all schools and used as part of an after-school program. Such a module-based program is meant to encourage S&T teachers to keep abreast with the latest scientific developments. Preparation for national competitions should also naturally result in region-based discussion groups of math and science teachers, closer interaction of students and teachers (as mentors), and overall improvement of math and science instruction in regular classes.

Different interventions are recommended for students who already show an inclination towards S&T courses. For select science high schools:

- **Raise support for selected science high schools for more advanced pedagogy.** Provide laboratory equipment such as UP NIP's DOST-funded VISSER (Versatile Instrumentation System for Science Education and Research) modular instruments for training students in experimental and quantitative science. The Tanza Child Development Center's robotics program, which introduces programming and engineering construction even at the primary levels, is also worth emulating and should be recommended for incorporation in their STEM programs.

- **Organize university-led summer enrichment programs with corresponding certifications.** Many science camps led by DOST-Science Education Institute (DOST-SEI) and corporate foundations focus on field-based activities meant to encourage students to pursue STEM degrees. The envisioned enrichment program is a bridging program for select students. While it will still be conducted in an age-appropriate manner, the primary goal is to re-teach Natural Science and Math subjects' foundations for critical thinking skills development.

Improvement in math and science comprehension can be tracked if DEPED will institutionalize standardized nationwide testing. Such tests may be formulated in such a way that questions would lean heavily on testing students' critical thinking skills.

2. Increasing PhD faculty and S&T research in SUCs and HEIs

State Colleges and Universities (SUCs) and private Higher Education Institutions (HEIs) play a critical role in supplying the workforce that drives the S&T ecosystem. Republic Act 10931 not only mandates free tuition to all public Tertiary education institutions but stresses access to quality education. Outputs of excellent Universities are now reasonably standardized (e.g., publications, patents, technology transfer, societal impacts, etc.) and typically result from a highly trained and motivated faculty roster in a research-driven academic environment.

- **Provide robust, enabling support to faculty in SUCs by lobbying for measures that increase research productivity**, especially for early-career researchers, including:
    1. Reduction of faculty teaching units when engaged in funded research;
    2. Financial incentives for those engaged in R&D projects; and
    3. Encourage research that tackles region-based problems.

  Indeed, the Philippine Association of State Universities and Colleges (PASUC) and the Philippine Association of Colleges and Universities (PACU) encourage teaching de-loading as a standard practice across all SUCs and HEIs. Along with incentives to conduct R&D, this should encourage new PhD graduates to apply for tertiary faculty positions, enabling them to continue their research work. Moreover, promoting region-based thinking encourages SUCs to integrate their faculty and resource pools regionally instead of competing against each other.

  Regarding strengthening regional universities:

- **Institute research-based programs in select Universities with corresponding DOST scholarships specific to SUC faculty**. Research-based PhD programs, such as those in UP Diliman, should accommodate distance learning modes. Such scholarship would include short-term training in field and lab-based methods with the host institution and postdoc training abroad. In the latter, PAASE members based in foreign institutions should play an active role both in the online teaching of courses and in co-advising MS or PhD theses and hosting postdoctoral researchers in their laboratories.

  Related to tapping foreign-based scientists, hiring Filipinos with foreign or dual citizenship as faculty members will effectively increase the talent pool available to SUCs. While previous restrictions have already been relaxed under EO 65 (11th Regular Foreign Investment Negative List), and subsequent related laws, current rules and practice of hiring in public education institutions have yet to sufficiently adopt these.

- **Establish a national university in Mindanao.** Consider elevating the Mindanao State University (MSU) System, with the MSU Iligan Institute of Technology (MSU IIT) as its flagship campus, to become the country's second national university. Other universities in Mindanao may also be integrated into the MSU System. As such, government support is required to level up both its facilities and faculty composition as appropriate for a national research university. The latter requires recruiting the best and brightest faculty members, elevating the quality of teaching, research, and extension work to be at par with the ASEAN's best schools.

3. Increasing PhD faculty and S&T research in SUCs and HEIs

The increase in demand for S&T workers should inevitably come from the agro-industrial sectors. Demand will come from region-based, high intellectual capital industries requiring technical personnel in manufacturing and also in R&D for process and product improvement.

- **Incentivize industry involvement in academic programs** via the DOST and Department of Trade and Industries. As an entry point for industry-academe collaboration, companies can integrate their in-house training of employees/apprenticeship with formal courses in SUCs. Such an arrangement will initially result in graduates who are readily employable by the various industrial firms. Such a collaboration would address the perennial issue of skills mismatch raised by industries (STRIDE, 2019) and may also shepherd industry-driven R&D conducted in SUCs that will also increase employment for S&T researchers. Foreign-based Filipino scientists through the DOST Balik Scientist Program could be harnessed to provide the necessary support for DOST Niche Centers for R&D sites particularly those concentrating on research in the agro-industrial sector.

- **Create programs that promote technopreneurship** to S&T graduates. In the regions, SUCs (and DOST's Niche Center for R&D) may very well serve as catalysts for new businesses particularly in regional agro-industrial and manufacturing sectors. There is a growing number of examples of research outputs in SUCs/HEIs on the brink of commercialization. These need further support in terms of market discovery, business planning, and investment.

- **Help restructure the Tech-Voc programs offered by TESDA** to include training programs directly required by high intellectual capital industries. These should consist of training for higher value BPO services, sophisticated instrumentation and machinery, and computer programming-related work. Senior high school graduates can go straight to these short-term TESDA programs. DOST facilities and laboratories (ADMATEL, ACEM, etc.) may be used to train workers from viable large industries and MSMEs who can pay for training and make the facility sustainable.

Creation of S&T HCD Fund and Implementation Team

Some of the outlined strategies may very well be initiated and implemented by PAASE immediately. However, most strategies may be accomplished only with the cooperation of key government agencies particularly DEPED, DOST, CHED, DTI, and TESDA and the collaboration of SUCs and HEIs who share the same vision. The creation of an S&T Human Capital Development Fund and Implementation Team under the Office of the President is warranted to ensure a programmatic and time-bound accomplishment of strategies. A budget of one billion pesos over a 10-year period will result in significant improvements in measurable indicators outlined below, however, an even longer program and/or a larger budget will obviously have the potential to magnify intended results. Still, most important is to have a separate fund which would eliminate potential bureaucratic delays if inserted under the budgets of existing government agencies. Beyond organization, funding, and implementation, the committee administering the HCD funds may be guided by the recommended measurable indicators of accomplishment:

- Number of participants in PAASE-sponsored projects for high school students;
- Competence in math and science of public high school students as evidenced by the improvement of scores in national and international evaluation exams;
- Percentage of MS and PhD holders in SUCs and HEIs relative to current numbers;
- R&D output such as publications, patents, and partnerships with industry in regional SUCs and HEIs;
- Employment of S&T workers in industries as well as increase in agro-industrial activities in the regions; and,
- PAASE-initiated HCD programs with DOST, CHED, TESDA, and other government agencies.

REFERENCES

Materials for this paper were derived from presentations, including those from PAASE webinars on S&T HCD. Also used are publicly available reports, including the 2014 and 2019 Philippines Innovation Ecosystem Assessment by USAID-STRIDE, PIDS' 2019 report on Future S&T Human Resource Requirements in the Philippines: A Labor Market Analysis, ADB's 2007 Technical report entitled, Moving toward knowledge-based economies: The Asian experience, and, DOST's Manual for M&E Protocol.