The Elusive Critical Mass of Research Scientists and Engineers (RSEs)

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Summary

In 2017, the Department of Science and Technology (DOST) S&T Human Resource Plan targeted to attain the UNESCO benchmark of 380 research scientists and engineers (RSEs) per million population by 2022. This translated to an additional 16,652 R&D personnel over a 6-year period to meet the benchmark by 2021, assuming a 10% annual attrition rate of RSEs. This study aimed to (a) determine the number of RSEs needed in 2022 to 2045 to attain the UNESCO level at 0, 5, and 10% attrition rates assuming that the RSEs will have at least an MS degree, and (b) analyze what actions to take in improving the quality and quantity of RSEs. If only MS and PhD graduates are considered eligible to join the ranks of RSEs, data showed that the required number of new RSEs per year cannot be satisfied in 2022 and for several years thereafter. The current capacity of the STEM graduate education sector was noted to be significantly inadequate and considering the long gestation periods in academe, it will take considerable time to build up to the required capacity.

The following actions are recommended: (a) increase the overall capacity and quality of STEM graduate education by incentivizing all concerned schools with CHED Centers of Development/Centers of Excellence (COD/COEs) to vertically articulate these BS programs up to the MS and PhD levels and for all concerned schools with MS and PhD STEM graduate programs to have their BS programs level up to COD/COE status; (b) increase the enrollment in and throughput of all STEM graduate programs; (c) increase the proportion of STEM MS and PhD graduates who go to R&D; and (d) lower the attrition rate of RSEs with incentives and better job opportunities in R&D in public and private sectors in the country.

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Introduction

The UNESCO estimates that 380 research scientists and engineers (RSEs) per million population are needed for a country to be able to take off towards industrialization. This so-called UNESCO benchmark could be used to quantify the oft-mentioned critical mass of RSEs that our country needs.

The DOST Science and Technology Human Resource Plan (2017-2022) (*1*) estimated in 2017 that the gap to be bridged is 110 RSEs per million. This translated to an additional 16,652 R&D personnel over a 6-year period to meet the benchmark by 2022. It assumed a 10% annual attrition rate of RSEs, *i.e.*, the rate at which RSEs leave the pool. It determined thus that 3,663 STEM graduates need to enter the pool every year. The plan stated further that if there is an *"almost 100% increase in the number of (DOST-SEI) scholarship slots both at the undergraduate and the graduate levels starting 2018"* and that if *"all available slots are subscribed and that only 30% of the scholar-graduates go into R&D,"* the gap should be filled by 2021 (*1*).

This study assumes that the target will be met in said year. It focuses on the situation beyond 2021. It assumes that the additional RSEs must have at least a STEM master's degree. This is different from what Reference 1 assumes, *i.e.*, that STEM BS graduates can join the ranks of RSEs straight out of college.

Reference 2 recommended that "*After a selection process, the streams of graduates from the three national systems of science high schools, numbering about 12,700 every year, should be funneled and shepherded through college and graduate school.*" Reference 3 elaborated on such funneling. This paper extracts from and builds upon the topic of funneling found in Reference 3.

Requirements beyond 2021

Assuming that the UNESCO benchmark is already met by 2021, Table 1 shows the number of RSEs required beyond that year in order to maintain being at the level of the benchmark.

It is assumed that the Philippine population in mid-2020 is 109,581,098 (*4*) and in 2045 will be 142 million (*5*). This gives a uniform annual growth rate of 1.042%. The use of a uniform growth rate should be sufficient for purposes of this study. Three attrition rates are considered: 0%, 5%, and 10%.

It can be seen in Table 1 that the required number of new RSEs appears modest at 0% attrition rate. However, compensating for the attrition of RSEs drives the requirement up by an order of magnitude.

It may also be noted that the annual incremental increase in the required new RSEs under all assumed attrition rates is modest. This means that after the initial task of reaching the UNESCO benchmark is accomplished, through a massive scholarship program as the DOST-SEI is doing, then the required yearly increase in capacity of the system to turn out new RSEs eases up and should be easier to attain if the goal is to just hover at the level of the UNESCO benchmark. However, the country should really aspire to exceed said benchmark.

The current number of STEM graduates

Will the present education system be able to supply the required number of RSEs shown in Table 1?

Table 2 shows the number of STEM graduates at BS, MS, and PhD levels for all programs and for the subset composed of programs considered as CHED Centers of Development and Centers of Excellence (COD/COEs). The data are for AY 2016-2017. This study assumes that such data sufficiently approximates the figures for the ensuing years.

Considering all programs, the total number of MS and PhD STEM graduates is 1,435. If, as in Reference 1, 30% , or 430 graduates, are assumed to join the ranks of RSEs the number falls only slightly short of requirements at 0% attrition rates, but is an order of magnitude below requirements at 5% and 10% attrition rates. Instead of hundreds of graduates, there should be thousands of graduates.

Table 1. Required number of new RSEs annually beyond to maintain being at the level of the UNESCO benchmark under various attrition rate assumptions.

Year	Population	Required No. of RSEs	Required New RSEs at Various Attrition Rates		
			0%	5%	10%
2020	109,581,098	41,641	assumed met	assumed met	assumed met
2021	110,722,933	42,075			
2022	111,876,666	42,513	438	2,542	4,646
2023	113,042,421	42,956	443	2,569	4,694
2024	114,220,323	43,404	448	2,595	4,743
2025	115,410,499	43,856	452	2,622	4,793
2026	116,613,076	44,313	457	2,650	4,843
2027	117,828,184	44,775	462	2,677	4,893
2028	119,055,954	45,241	467	2,705	4,944
2029	120,296,517	45,713	471	2,733	4,996
2030	121,550,007	46,189	476	2,762	5,048
2031	122,816,558	46,670	481	2,791	5,100
2032	124,096,306	47,157	486	2,820	5,153
2033	125,389,390	47,648	491	2,849	5,207
2034	126,695,947	48,144	496	2,879	5,261
2035	128,016,119	48,646	502	2,909	5,316
2036	129,350,047	49,153	507	2,939	5,372
2037	130,697,875	49,665	512	2,970	5,427
2038	132,059,746	50,183	518	3,001	5,484
2039	133,435,809	50,706	523	3,032	5,541
2040	134,826,210	51,234	528	3,064	5,599
2041	136,231,099	51,768	534	3,096	5,657
2042	137,650,627	52,307	539	3,128	5,716
2043	139,084,947	52,852	545	3,160	5,776
2044	140,534,212	53,403	551	3,193	5,836
2045	141,998,578	53,959	556	3,227	5,897

Table 2. Number of STEM graduates per program level AY 2016-2017 based on data from reference 6.

	BS	**MS**	**PhD**
All programs	110,011	1,313	122
COD/COE BS programs and COD/COE-based MS & PhD programs	9,910	380	62

If only the graduates of MS and PhD programs that are based on COD/COE BS programs are considered, then there are 442 graduates. Thirty percent of this is 132 graduates and is several multiples shy of the requirements at 0% attrition rate.

If a 5% or a 10% attrition rate is assumed then the total number of MS and PhD graduates of COD/COE-based programs will have to be increased by an order of magnitude in order to meet the requirements.

If RSEs are required to have at least a master's degree, then the present capacity of the Philippine educational system is woefully inadequate and cannot satisfy the requirements in the year 2022 and for several more years after that until the capacity is suitably increased.

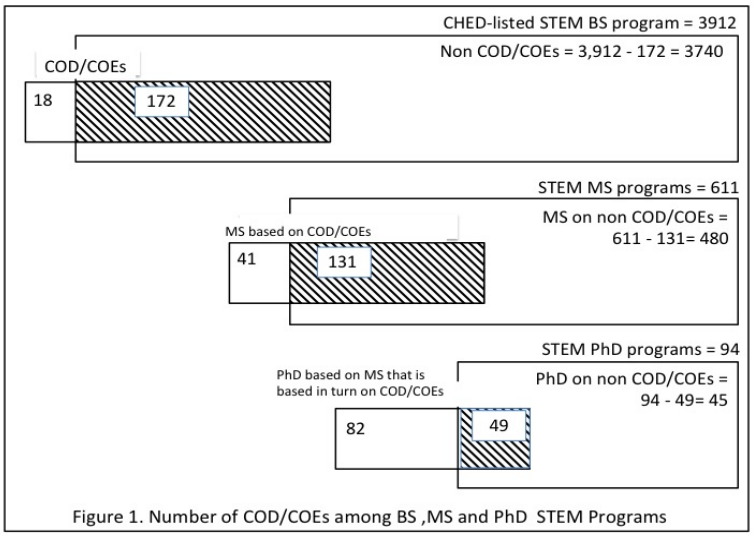

Figure 1. Number of COD/COEs among BS ,MS and PhD STEM Programs

Increasing capacity

Figure 1, which is based on CHED data of AY 2016-2017 (*6*), shows that there are 3,912 BS STEM programs. It also shows that there are 172 COD/COEs. There is a gap in data: there are 18 other COD/COEs not in the list of 3,912 CHED programs. We are thus able to track only the 172 COD/COEs.

Vertically articulating the COD/COEs to PhD

Of these 172 COD/COEs, 131 are vertically articulated to MS programs and 41 are not. Of the 131 articulated programs, 49 are further articulated to PhD programs and 82 are not.

An increase in the capacity to produce better qualified RSEs could therefore come from: 1) articulating the 41 COD/COE programs to MS and then to further articulating them to PhD; and 2) articulating the 82 MS programs to PhD.

Strengthening the foundation of MS & PhD programs not currently built upon COD/COEs

Figure 1 shows that there are 611 MS STEM programs. Of these, 480 are not built upon COD/COEs. The figure also shows that there are 94 PhD STEM programs, of these, 45 are not built upon MS programs that are in turn not based on COD/COE programs.

It may be seen that a further increase in the capacity to produce better qualified RSEs can come from improving the quality of the non-COD/COE BS programs upon which MS and PhD programs are built by elevating them to COD/COE status.

Estimates of increase in capacity

This section estimates the increase in capacity in terms of the number of COD/COE-based MS and PhD programs arising from the suggested actions in the previous section.

Increase in the number of programs

Table 3 shows the increase in the number of COD-COE-based MS and PhD programs per action taken. Actions 2, 3, and 4 can run parallel to actions 5 and 6. Actions 2 and 3 can be done in parallel. Action 2 must precede action 4. Action 5 must precede action 6. Needless to say, all these actions will have to be programmed over a number of years.

Table 3. Number of additional new programs resulting from actions to increase capacity to produce RSEs.

No.	Action taken	No. of COD/COE-based STEM MS programs			No. of COD/COE-based STEM PhD programs		
		Base	Added	Total	Base	Added	Total
1	No action	131	0	131	49	0	49
2	Articulate 41 COD/COE programs to MS	131	41	172			
3	Articulate 82 MS COD/COE-based programs to PhD				49	82	131
4	Articulate the 41 MS programs in item 2 further to PhD				131	41	172
5	Elevate to COD/COE status the BS programs upon which 480 MS programs are built.	172	480	652			
6	Elevate the 480 MS programs in item 5 further to PhD				172	480	652

Note: *The MS programs of the 45 PhD programs not built upon COD-COE programs are already counted in 480 MS programs.*

Increase in the number of graduates

Presently, from the 131 COD/COE-based MS STEM programs come 380 graduates. This corresponds to an average of 2.9 graduates per program per year. From the 49 COD/COE-based PhD STEM programs come 62 graduates. This corresponds to an average of 1.3 graduates per program per year. These are very low figures.

In the simulation to follow, it is assumed that there will be 20 graduates per MS program and 5 graduates per PhD program per year. This is a reasonable assumption given what schools in other countries are able to do. Given the very low number of graduates per program at present, it will take a significant amount of time to ramp up to these values.

From Table 1, roughly around 5000 RSEs will be needed every year over the years at a 10% attrition rate. Assuming, as in Reference 1 that 30% of graduates go into R&D, about 16,700 STEM graduates will be needed every year.

From among the actions in Table 2, what need to be taken and how many graduates per MS and PhD program should there be in order to get these 16,700 graduates?

Table 4 shows the estimated number of STEM graduates resulting from actions to increase capacity as listed in Table 3 with an assumption of 20 graduates per MS program and 5 graduates per PhD program per year.

Table 4 shows that taking actions 2, 3, and 4 yields 3,440 + 860 = 4,300 graduates, which is way below the requirement. If, additionally, actions 5 and 6 are taken, the number of graduates will be 4,300 + 13,040 + 3,260 = 20, 600, which is sufficient.

If the attrition rate were lowered to 5%, around 2,800 new RSEs are needed each year. At 30% conversion of graduates into RSEs, around 9,000 graduates would be needed. Taking only actions 2, 3, and 4 is still inadequate. Actions 5 & 6 still need to be taken in order to satisfy the requirements.

Table 4. Estimated number of STEM graduates resulting from actions to increase capacity to produce RSEs.

No.	Action taken *(same as in Table 3 except for item 1)*	No. of MS graduates per year (*assuming 20 per program*)		No. of PhD graduates per year (*assuming 5 per program*)	
		No. of programs	No. of graduates	No. of programs	No. of graduates
1	Increase average no. of graduates per year	131	2620	49	245
2	Articulate 41 COD/COE programs to MS	172	3440		
3	Articulate 82 MS COD/COE-based programs to PhD			131	655
4	Articulate the 41 in item 2 further into PhD			172	860
5	Elevate to COD/COE status the BS programs upon which 480 MS programs are built	652	13,040		
6	Elevate these 480 in item 5 further to PhD			652	3260

Conclusions

The required number of new RSEs per year, assuming they are MS and PhD level graduates, cannot be satisfied in 2022 and for several years thereafter. The current capacity of the STEM graduate education sector is significantly inadequate and considering the long gestation periods in academe, it will take considerable time to build up to the required capacity. How much time it will take will depend upon the programming and implementation of the actions to vertically articulate a number of academic programs and to strengthen the foundation of a number of other programs. The time to attain the required capacity will also depend on the speed at which the number of graduates per program per year can be ramped up.

Recommendations

The following actions are recommended:

1. Increase the overall capacity of STEM graduate education by incentivizing all concerned COD/COEs to articulate up to the MS and PhD levels and by incentivizing all concerned STEM graduate programs to have their undergraduate programs level up to COD/COE status;
2. Provide an adequate number of STEM graduate scholarships to match through time the increasing system capacity arising from item 1 above;
3. Increase the enrollment in and throughput of all STEM graduate programs;
4. Increase the proportion of STEM MS and PhD graduates who go to R&D; and
5. Lower the attrition rate of RSEs with the grant of incentives and other measures.

Areas of further study

This study has located the ballpark and given a handle on the magnitudes of major variables involved in building a critical mass of RSEs. It can be extended by programming the actions to boost the capacity of the STEM graduate education sector by increasing the number of high-quality programs and the number of graduates of such programs.

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4. https://www.worldometers.info/world-population/philippines-population/

5. https://psa.gov.ph/statistics/census/projected-population

6. Data provided by the CHED Office of Planning, Research and Knowledge Management (OPRKM)- Knowledge Management Division; Includes baccalaureate up to doctoral programs; Based on the submission of higher education institutions as of February 19, 2019.

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The National Academy of Science and Technology Philippines (NAST PHL) is mandated to recognize outstanding achievements in science and technology and to serve as reservoir of competent scientific and technological manpower for the country (Presidential Decree No. 1003-A, December 17, 1976). By virtue of Executive Order 818 (July 16, 1982), the Academy was formally charged with the function of advisory body to the President and the Cabinet on policies concerning science and technology in the country.

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