THE LANCET

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Frenk J, Chen LC, Chandran L, et al. Challenges and opportunities for educating health professionals after the COVID-19 pandemic. *Lancet* 2022; **400:** 1539–56.

WEB ANNEX

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Annex 1: Estimation of Country-Level Medical Education Costs and Health Worker Production

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In order to estimate country-level expenditures on medical education, we adopted a "micro-level" approach in which we multiply the estimated cost per graduate by worker group (w) in 2018 (t) for each country (c) by and an estimate of the number of graduates for each cadre in 2018 for each country (Eq. 1). The global (or regional) annual costs represent the sum of expenditures across relevant countries. We also can estimate global (or regional) production of health workers. The basic formulas are indexed by worker type (w, physician, or nurse/midwife), country (c) and time (t, 2018):

$$Eq.1 \quad Expenditure_{w,c,t} = Cost\ per\ Graduate_{w,c,t} * Graduates_{w,c,t}$$

$$Eq.2 \quad Global\ Expenditure_{w,t} = \sum_{c} Expenditure_{w,c,t}$$

$$Eq.3 \quad Global\ Production_{w,t} = \sum_{c} Graduates_{w,c,t}$$

Estimating Cost per Graduate
We estimated cost per graduate either A) directly from literature (n=56 estimates across 47 countries) or B) indirectly via predictive regression analysis.

Direct Cost per Physician Graduate Estimates
There are 3 main types of sources used for direct estimates.

1) Economic Assessments (highest quality; n=15)
2) Tuition / Budget Based Estimates (high quality—but generally require assumptions about ratio of tuition revenue to costs, in some cases based on financials in public institutions or private medical schools; n=37)
3) Expert Opinion (high quality; n=4)

Table 1 summarizes the estimate values. In each case we A) update the estimate to adjust for country inflation between the year of the study and 2018 based on World Bank CPI data, B) convert to $US (2018) based on World Bank Exchange Rate, C) adjust units required for graduation (e.g. if estimates are reported in cost per year, we multiply by the relevant number of years for graduation of the medical student) and D) in select cases, make minor adjust for missing capital costs.

Table 1.A: Cost per Graduate Estimates (n=15), Economic Studies

Country	Estimated Cost per Graduate ($US, 2018)	GDP/Capita ($US, 2018)	Source(s)
Australia	$319,146	$57,396	[1,2]
Brazil	$86,514	$9,001	[3]
Canada	$232,557	$46,313	[4]
Columbia	$62,669	$6,719	[5]
Ghana	$45,738	$2,202	[6-8]
Iran	$59,170	$5,520	[9]
Ireland	$177,604	$78,621	[10]
Thailand	$93,910	$7,295	[11]
United Kingdom	$252,148	$43,043	[12]
United States	$528,309	$62,840	[13]
United States	$516,523	$62,840	[14]
United States	$588,287	$62,840	[15]
United States	$461,349	$62,840	[16]
United States	$378,152	$62,840	[17]

Table 1.B: Cost per Graduate Estimates (n=37), Budget/Tuition Estimates

Country	Estimated Cost per Graduate ($US, 2018)	GDP/Capita ($US, 2018)	Source(s)	Comment
Antigua	$145,784	$16,727	American University of Antigua[18]	Assumes listed international price reflects reasonable proxy for cost
Aruba	$55,319	$29,008	Aureus University School of Medicine[19]	Assumes listed international price reflects reasonable proxy for cost
Australia	$328,667	$57,396	Monash University School of Medicine[20]	Assumes international listed price divided by ratio of 'tuition income / total operating expenditure (less depreciation)' from income statement is a reasonable proxy for cost (2015 International Tuition MD per year = 56,300 SGD) / (388,131/642,906)
Bangladesh	$30,041	$1,698	[21]	Assumes that regulators 'cap' on private tuition is a reasonable estimate of total cost
Barbados	$68,681	$17,745	American University of Barbados[18]	Assumes listed international price reflects reasonable proxy for cost
Belize	$76,565	$4,885	American Global University School of Medicine[22]	Assumes listed international price reflects reasonable proxy for cost
China, People's Republic of	$41,209	$9,977	China Medical University[23]	Assumes listed international price reflects reasonable proxy for cost
Cyprus	$127,839	$28,690	University of Nicosia Medical School[24]	Assumes listed international price reflects reasonable proxy for cost
Czech Republic	$134,989	$23,047	Charles University[25]	Assumes listed price reflects reasonable proxy for cost - recently formed private (1979) university
Dominica	$49,636	$7,691	All Saints University of Medicine[26]	Assumes listed international price reflects reasonable proxy for cost
Ethiopia	$14,473	$772	St. Pauls Hospital Millenium Medical College[27]	Assumes listed international price reflects reasonable proxy for cost
Ethiopia	$39,036	$772	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Germany	$286,190	$47,639	Tuebingen University[29]	Assumes medical school budget / # students reflects annual cost per student
Grenadines	$51,281	$7,361	American University of St. Vincent School of Medicine[18]	Assumes listed international price reflects reasonable proxy for cost
Guyana	$64,105	$4,979	American International School of Medicine[30]	Assumes listed international price reflects reasonable proxy for cost
India	$69,839	$2,006	Joy et al., IHEA 2007 Presentation[31]	Assumes private sector tuition approximates cost
Jamaica	$74,833	$5,354	All American Institute of Medical Sciences[32]	Assumes listed international price reflects reasonable proxy for cost
Jordan	$141,877	$4,242	University of Jordan[33]	Assumes listed international price reflects reasonable proxy for cost
Kenya	$86,974	$1,708	University of Nairobi, Tuition Price List, 2015[34,35]	Asssumes 50/50 split in merit vs non-merit students and 'academic departments' costs are attributed 50% to tuition (lower level for other cost components)
Kenya	$44,727	$1,708	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Laos	$17,076	$2,542	WHO, FAIMER[36,37]	Assumes that the weighted average of cost per year is $1500 and Nurses cost per year is $1200, given the ratio physicians to health worker ratio in Laos (2016) was .18 (2,107/11,561), the estimated cost per MD is $2846 per year
Lebanon	$214,630	$8,025	American University in Beirut[38]	Assumes price divided by ratio of 'tuition income net of financial aid' / 'total education service expense' from income statement is a reasonable proxy for cost (2015 Tuition MD per graduate = $36,382 $US) / (134,879,943/17,924,000); tuition figure is MD specific; tuition income and education service expense is university wide ratio.
Malawi	$25,030	$381	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost

Malaysia	$89,332	$11,373	MAHSA University School of Medicine[39]	Assumes listed price reflects reasonable proxy for cost
New Zealand	$300,164	$42,950	University of Auckland[40]	Assumes international listed price divided by ratio of 'tuition income / total operating expenditure (less depreciation)' from income statement is a reasonable proxy for cost (2015 International Tuition MD per year = 56,300 SGD) / (388,131/642,906)
Nigeria	$40,083	$2,033	Lagos State University[41]	
Nigeria	$27,432	$2,033	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Philippines	$73,688	$3,252	Fatima University SOM[42]	Assumes listed price reflects reasonable proxy for cost - recently formed private (1979) university
Poland	$89,604	$15,461	Poznan University[43]	Assumes listed price reflects reasonable proxy for cost - well established school with international program (mark-up above cost?)
Saint Lucia	$62,675	$11,358	Atlantic University School of Medicine[30]	Assumes listed international price reflects reasonable proxy for cost
Singapore	$509,388	$66,189	NUS-Duke University[44,45]	Assumes international listed price divided by ratio of 'tuition income / total operating expenditure (less depreciation)' from income statement is a reasonable proxy for cost (2015 International Tuition MD per year = 56,300 SGD) / (388,131/642,906)
South Africa	$32,203	$6,374	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Sweden	$165,249	$54,589	Karolinska Institutet, Annual Report 2014[46]	Share of Bachelors and Masters students in Medicine (FTE) = 2,135/5,336 (p.17), Costs for Bachelors and Masters Program 818.8 M SEK (2008) p.22, Medical Degrees conferred 249 (p. 100)-->1.32 SEK per graduate
Tanzania	$26,321	$1,061	Hubert Kairuki Memorial University[47]	Assumes listed price reflects reasonable proxy for cost - recently formed private university
Tanzania	$26,002	$1,061	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Uganda	$18,753	$767	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost
Zambia	$17,924	$1,556	Mills et al., 2011[28]	Assumes Mills et al. estimate is reflective of cost

Table 1.C: Cost per Graduate Estimates (n=4), Expert Assessment

Country	Estimated Cost per Graduate ($US, 2018)	GDP/Capita ($US, 2018)	Source(s)
Czech Republic	$84,810	$23,047	Martin Potucek[48]
Germany	$221,733	$47,639	Thomas Reinhold[49]
Norway	$152,949	$81,734	Tor Iverson[50]
Slovakia	$43,026	$19,428	Martin Potucek[48]

Cost per graduate for each country was estimated in $US 2018 dollars (exchange rate estimate). In instances where direct evidence on the cost per graduate exists in available literature, those values were used for the country level estimation (in most models). In cases where there is more than one direct estimate for a country, the average is used.

We have increased the number of direct estimates relative to prior efforts as indicated in Table 2.

Table 2: Cost per Physician Estimates across Studies

		2010 Commission (2008)	2015 WHO (2013)	2021 Commission (2018)
Cost per MD Graduate Estimates for Regression	**Economic Studies**	9	10	15
	Financial Analysis*	0	39	37
	Expert Estimate	1	4	4
	Total Studies	10	53	56
	Total Countries	7	43	47

*Budget or Tuition Based Estimates

Indirect 'Cost per Physician Graduate' Estimates

For those countries without a direct estimate of 'cost per physician graduate', we rely on regression models to estimate the expected cost. Specifically, we use Generalized Linear Models (GLM), a commonly used approach in health economics[51], and use various covariates depending on the model.

Potential covariates include:

- GNI/Capita ($US, 2018)
- Income Band (4 Categories: High Income, Upper Middle Income, Lower Middle Income, Low Income, based on World Bank 2018 designation)
- Region (Regression Regions: Africa, Asia/Middle East, Europe, Latin America Caribbean, North America, Oceania)

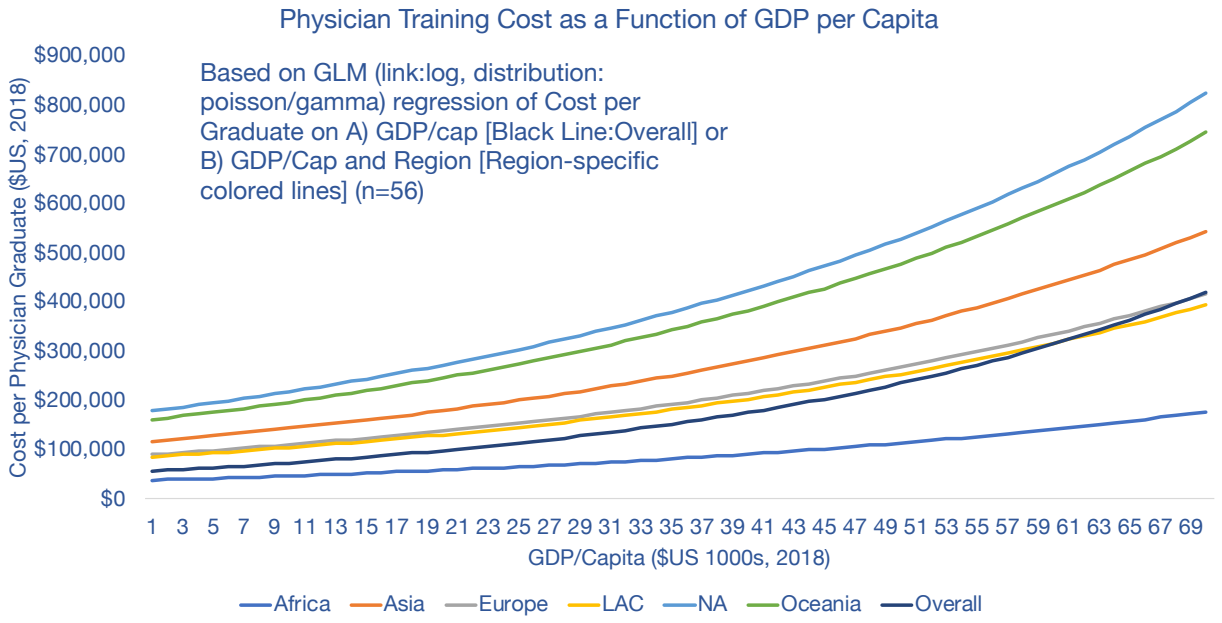
In the GLM framework, we use a 'log' link function and either a 'poisson' or 'gamma' distribution depending on specific model -- the diagnostic recommendation as suggested in Deb et al (2017). Based on regression results, we estimate predictions of 'cost per physician graduate' (overall and for each region) based on the GNI/capita of the country. The results are reflected in Table 3 and Figure 1.

Table 3: Predicted Cost per Physician Graduate based on GNI/Capita, (by region)

		Cost Per Physician Graduate (by Region and Income Level)						
		1 Africa	2 Asia	3 Europe	4 LAC	5 NA	6 Oceania	Overall
GNI / Capita ($US 1000s, 2018)	$1	$38,398	$117,803	$90,483	$85,657	$178,721	$161,444	$56,550
	2	$39,259	$120,442	$92,511	$87,576	$182,725	$165,062	$58,219
	3	$40,138	$123,141	$94,583	$89,538	$186,819	$168,760	$59,937
	4	$41,038	$125,900	$96,702	$91,544	$191,005	$172,541	$61,706
	5	$41,957	$128,720	$98,869	$93,595	$195,284	$176,407	$63,527
	6	$42,897	$131,605	$101,084	$95,692	$199,660	$180,359	$65,401
	7	$43,858	$134,553	$103,349	$97,836	$204,133	$184,400	$67,331
	8	$44,841	$137,568	$105,665	$100,028	$208,707	$188,532	$69,318
	9	$45,846	$140,650	$108,032	$102,269	$213,383	$192,756	$71,364
	10	$46,873	$143,801	$110,453	$104,561	$218,164	$197,075	$73,470
	11	$47,923	$147,023	$112,927	$106,904	$223,052	$201,490	$75,638
	12	$48,997	$150,317	$115,458	$109,299	$228,049	$206,005	$77,871
	13	$50,094	$153,685	$118,044	$111,748	$233,159	$210,620	$80,169
	14	$51,217	$157,129	$120,689	$114,251	$238,383	$215,339	$82,535
	15	$52,364	$160,649	$123,393	$116,811	$243,724	$220,164	$84,970
	16	$53,538	$164,249	$126,158	$119,428	$249,185	$225,097	$87,478
	17	$54,737	$167,929	$128,985	$122,104	$254,768	$230,140	$90,059
	18	$55,963	$171,691	$131,875	$124,840	$260,476	$235,296	$92,717
	19	$57,217	$175,538	$134,829	$127,637	$266,312	$240,568	$95,453
	20	$58,499	$179,471	$137,850	$130,497	$272,279	$245,958	$98,270
	21	$59,810	$183,492	$140,939	$133,421	$278,379	$251,469	$101,171
	22	$61,150	$187,603	$144,096	$136,410	$284,616	$257,103	$104,156
	23	$62,520	$191,806	$147,325	$139,466	$290,993	$262,864	$107,230
	24	$63,921	$196,104	$150,626	$142,591	$297,513	$268,753	$110,395
	25	$65,353	$200,498	$154,001	$145,786	$304,179	$274,775	$113,652
	26	$66,817	$204,990	$157,451	$149,052	$310,994	$280,931	$117,006
	27	$68,314	$209,583	$160,979	$152,392	$317,962	$287,226	$120,460
	28	$69,845	$214,278	$164,586	$155,806	$325,086	$293,661	$124,014
	29	$71,410	$219,079	$168,273	$159,297	$332,370	$300,241	$127,674
	30	$73,010	$223,988	$172,043	$162,866	$339,816	$306,967	$131,442
	31	$74,646	$229,006	$175,898	$166,515	$347,430	$313,845	$135,321
	32	$76,318	$234,137	$179,839	$170,246	$355,214	$320,877	$139,315
	33	$78,028	$239,383	$183,868	$174,060	$363,173	$328,066	$143,426
	34	$79,776	$244,747	$187,988	$177,960	$371,310	$335,417	$147,659
	35	$81,564	$250,230	$192,200	$181,948	$379,629	$342,932	$152,016
	36	$83,391	$255,837	$196,506	$186,024	$388,135	$350,615	$156,503
	37	$85,260	$261,569	$200,909	$190,192	$396,831	$358,471	$161,121
	38	$87,170	$267,430	$205,410	$194,453	$405,722	$366,503	$165,876
	39	$89,123	$273,421	$210,013	$198,810	$414,813	$374,714	$170,771
	40	$91,120	$279,547	$214,718	$203,265	$424,107	$383,110	$175,811
	41	$93,161	$285,811	$219,529	$207,819	$433,609	$391,693	$181,000
	42	$95,249	$292,214	$224,448	$212,475	$443,324	$400,469	$186,341

43	$97,383	$298,762	$229,476	$217,236	$453,257	$409,442	$191,840
44	$99,565	$305,455	$234,618	$222,103	$463,412	$418,616	$197,502
45	$101,795	$312,299	$239,874	$227,079	$473,795	$427,995	$203,330
46	$104,076	$319,296	$245,249	$232,167	$484,411	$437,584	$209,331
47	$106,408	$326,450	$250,744	$237,369	$495,264	$447,388	$215,509
48	$108,792	$333,764	$256,362	$242,687	$506,361	$457,412	$221,869
49	$111,230	$341,243	$262,106	$248,124	$517,706	$467,661	$228,416
50	$113,722	$348,888	$267,978	$253,684	$529,305	$478,139	$235,157
51	$116,270	$356,705	$273,982	$259,367	$541,164	$488,852	$242,097
52	$118,875	$364,697	$280,121	$265,179	$553,289	$499,805	$249,242
53	$121,538	$372,868	$286,397	$271,120	$565,686	$511,003	$256,597
54	$124,261	$381,223	$292,814	$277,195	$578,360	$522,452	$264,170
55	$127,045	$389,764	$299,375	$283,405	$591,318	$534,158	$271,966
56	$129,892	$398,497	$306,082	$289,755	$604,567	$546,126	$279,992
57	$132,802	$407,425	$312,940	$296,247	$618,113	$558,362	$288,255
58	$135,778	$416,554	$319,951	$302,884	$631,962	$570,872	$296,761
59	$138,820	$425,887	$327,120	$309,671	$646,121	$583,662	$305,519
60	$141,930	$435,429	$334,449	$316,609	$660,597	$596,740	$314,536
61	$145,110	$445,185	$341,943	$323,703	$675,398	$610,110	$323,818
62	$148,361	$455,159	$349,604	$330,955	$690,531	$623,779	$333,374
63	$151,685	$465,357	$357,437	$338,370	$706,002	$637,755	$343,213
64	$155,084	$475,784	$365,445	$345,952	$721,820	$652,044	$353,341
65	$158,558	$486,444	$373,633	$353,703	$737,993	$666,654	$363,769
66	$162,111	$497,343	$382,005	$361,628	$754,528	$681,590	$374,504
67	$165,743	$508,486	$390,564	$369,730	$771,433	$696,861	$385,556
68	$169,457	$519,878	$399,314	$378,014	$788,718	$712,475	$396,935
69	$173,253	$531,526	$408,261	$386,483	$806,389	$728,438	$408,649
70	$177,135	$543,435	$417,408	$395,143	$824,456	$744,759	$420,709

Figure 1: Predicted Cost per Physician Graduate based on GNI/Capita, (by region)



We also run a regression in which only the 15 observations from the economic studies are used and compare it to the regression results that rely on all 56 observations. The results suggest somewhat larger estimates from the economic studies, but the results appear comparable.

Figure 2: Comparison of Regression Predictions using all observations (n=56) vs. economic study observations (n=15)

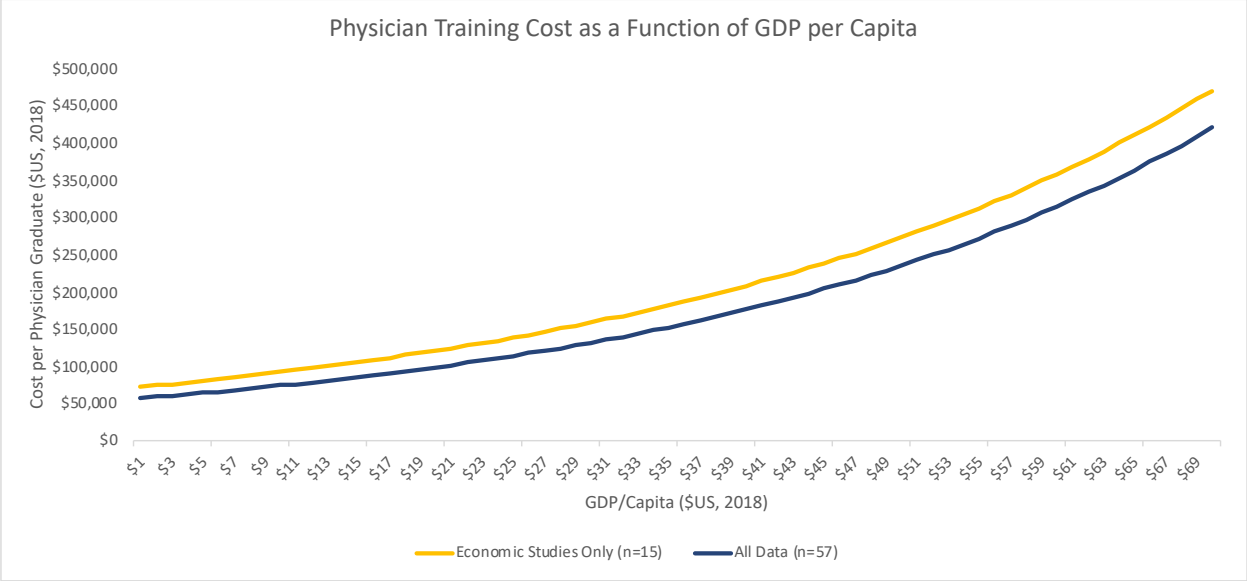


Table 4 summarizes the prediction by income band and region after running the GLM regression using region and income band covariates.

Table 4: Expected Cost per Physician by Income Band and Region

	Region					
	1	2	3	4	5	6
Income Band	Africa	Asia/ME	Europe	LAC	NA	Oceania
1	$24,323	$39,832	$29,074	$24,166	$70,730	$55,552
2	$36,177	$59,244	$43,243	$35,944	$105,200	$82,626
3	$76,690	$125,588	$91,668	$76,195	$223,008	$175,154
4	$168,079	$275,249	$200,907	$166,995	$488,761	$383,880

'Cost per Nurse/Midwife Graduate' Estimates

Given that the economic costing literature on nursing and midwives initially appears to be significantly less developed, we estimate cost per nursing graduate as a fixed fraction of physician 'cost per graduate' for each country. Based on prior work at the World Bank, we set this ratio at 0.2 (Duration of the nursing degree is assumed 50% as long and intensity of resource use is 40%-->.4*.5=.2).[52,1]

Estimating Number of Graduates

'Direct' Annual Graduate Estimates

For OECD countries, the graduate numbers were available and obtained from WHO Health Workforce Portal[53] which were cross-referenced with the OECD database[54]. The data aligned in most cases, with minor differences in which case WHO data was used over OECD for uniformity. Estimates that are prior to 2018 are updated to 2018 on the basis of population growth rate of the country between the time of the estimate and 2018 (Eq. 4). (This approach assumes graduates grow in proportion to population over time and differs from the 2010 approach,[55] which assumed no growth between the report year and 2008). Populations were sourced from the World Bank. Table 5 shows how the share of 'direct' estimates has increased over time.

$$Eq\ 4.\quad Graduates_{c,2018} = Graduates_{c,t} * \frac{Population_{c,2018}}{Population_{c,t}}$$

Table 5: Share of Graduate Estimates from Direct Estimates across Studies

		2010 Commission (2008)		2015 WHO (2013)		2021 Commission (2018)	
		Doctors	Nurse/MWs	Doctors	Nurse/MWs	Doctors	Nurse/MWs
Graduate Estimates	Percent if Countries Directly Reporting Graduates	17.5%	20.3%	33.8%	26.5%	25.0%	60.0%

The sum of 'Nurses' and 'Midwives' is used to estimate the total nurse/midwife category. Graduates are defined as number of students who have graduated from a given health workforce education and training programmes in professional schools or similar institutions in a given year. Overall, as indicated in Table 5, this study has a higher percentage of 'direct' estimates relative to prior efforts-with 35% of countries reporting an annual doctor graduate total and 60% of countries providing a nurse/midwife graduate total.

[1] In order to estimate scale up costs in Sub-Saharan Africa for medical education, a World Bank analysis estimated that the annual costs of an enrollee in a physician undergraduate education program are five times the annual costs of an average tertiary education student in each country. Nursing student costs are estimated at twice that of an average tertiary enrollee. Hence on a per year basis, the costs of a physician-in-training are 2.5 times that of a nursing candidate (Intensity Ratio). Assuming an average duration of enrollment is 3 years for nursing and 6 years for medicine, the duration of training is 2 times as long for a physician as a nurse (Duration Ratio). Multiplying the intensity ratio and duration ratios together, the estimated cost for a physician graduate is estimated at 5 times that of a nurse. Hence, in the base case we multiply the estimated costs for a physician graduate in each country by 0.2 to estimate cost per nursing graduate. We also apply this cost to midwives as nursing and midwife stock and production estimates are typically jointly estimated.

In select cases when no estimate exists in either OECD or WHO dataset, other resources are referenced. Table 6.A and 6.B summarize the estimates and sources for physicians and nurses/midwives direct graduate estimates.

Table 6.A: Direct Physician Graduate Estimates

Source: Physician Graduate Data	Country	Est. Number of MD Grads (2018): Population Adjustment
OECD[54]	Australia	3,958
	Austria	1,346
	Canada	2,860
	Czechia	1,700
	Denmark	1,335
	Germany	9,563
	Greece	1,331
	Hungary	1,560
	Iceland	48
	Ireland	1,224
	Israel	658
	Italy	9,103
	Korea (Rep.)	3,860
	Latvia	3,860
	Lithuania	577
	Netherlands	2,717
	Norway	542
	Portugal	1,760
	Slovakia	962
	Slovenia	281
	Switzerland	995
	Turkey	9,395
	United States	25,979
OECD/WHO[53,54]	Belgium	3,282
	Finland	645
	France	7,263
	Mexico	16,586
	Poland	4,006
	Spain	6,664
	Sweden	1,334
	United Kingdom	8,570
WHO[53]	Bosnia and Herzegovina	328
	Russian Federation	15,454
	Andorra	2

	North Macedonia	262
	Albania	258
	Romania	3,527
	Azerbaijan	1,189
	Kazakhstan	3,444
	Kyrgyzstan	1,828
	Tajikistan	0
	Turkmenistan	284
	Ukraine	3,733
	Uzbekistan	3,699
	Armenia	402
	Belarus	2,932
	Croatia	499
	Georgia	420
	Malta	119
	Serbia	1,340
	Bangladesh	5,512
	Bhutan	33
	Bulgaria	831
	Costa Rica	881
	Libya	1,116
	Mozambique	600
	Pakistan	16,332
	Chile	1,637
	Estonia	136
	India	127,846
	Iran, Islamic Republic of	6,261
	Iraq	2,631
	Japan	8,751
	Moldova	634
	Montenegro	30
	Myanmar	205
	New Zealand	2,733
	Nigeria	2,836
	Sri Lanka	1,200
	Thailand	2,470
	Timor-Leste	59
	Zimbabwe	207
National Center of Health Professions Education Development (PKU)[56]	China	83,204

Oxford Business Group,[57] Weill Medical Qatar Annual Report 2018[58]	Qatar	418

Table 6.B: Direct Nurse/Midwife Graduate Estimates

Source: Nurse/Midwife Graduate Data	Country	Est. Number of MD Grads (2018): Population Adjustment
OECD[54]	Australia	25,274
	Austria	2,936
	Canada	20,951
	Czechia	1,681
	Denmark	2,752
	Germany	44,517
	Greece	9,029
	Hungary	6,177
	Iceland	208
	Ireland	1,533
	Israel	2,217
	Italy	12,248
	Korea, Rep.	53,080
	Latvia	553
	Lithuania	644
	Luxembourg	76
	Netherlands	10,101
	Norway	4,378
	Portugal	2,580
	Slovakia	1,517
	Slovenia	1,657
	Switzerland	9,208
	Turkey	18,446
	United States	206,420
OECD/WHO[53,54]	Belgium	7,994
	Finland	4,937
	France	27,911
	Mexico	19,464
	Poland	5,309
	Spain	10,300
	Sweden	4,362
	United Kingdom	22,618
WHO[53]	Afghanistan	4,507
	Albania	540

	Algeria	994
	Andorra	2
	Angola	727
	Antigua and Barbuda	20
	Armenia	525
	Azerbaijan	377
	Bangladesh	6,450
	Barbados	89
	Belarus	255
	Belize	50
	Bhutan	194
	Bosnia and Herzegovina	432
	Botswana	392
	Bulgaria	542
	Burkina Faso	4,899
	Burundi	49
	Chile	6,282
	Congo, Dem. Rep.	370
	Cook Islands	6
	Costa Rica	137
	Croatia	1,088
	Cyprus	272
	Dominican Republic	1,659
	El Salvador	493
	Eritrea	575
	Estonia	424
	Eswatini (swaziland)	298
	Ethiopia	2,281
	Fiji	43
	Gambia, The	125
	Georgia	16
	Ghana	13,078
	Guatemala	1,177
	Guyana	225
	India	322,827
	Iran, Islamic Republic of	11,673
	Iraq	44,391
	Jamaica	418
	Japan	59,486

	Jordan	153
	Kazakhstan	12,913
	Kenya	7,432
	Kiribati	15
	Korea, Dem. People’s Rep.	20,020
	Lao People's Democratic Republic	169
	Lebanon	2,037
	Lesotho	304
	Libya	267
	Madagascar	163
	Malawi	2,173
	Malaysia	5,367
	Maldives	134
	Malta	184
	Moldova	810
	Monaco	30
	Montenegro	55
	Morocco	492
	Mozambique	1,536
	Myanmar	3,797
	Namibia	274
	New Zealand	2,081
	North Macedonia	218
	Oman	95
	Papua New Guinea	484
	Paraguay	1,046
	Romania	3,696
	Russian Federation	2,333
	Rwanda	1,109
	Samoa	10
	Serbia	1,290
	South Africa	10,192
	Sri Lanka	3,700
	St. Vincent and the Grenadines	47
	Sudan	77
	Tajikistan	11,521
	Thailand	10,670
	Timor-Leste	119
	Trinidad and Tobago	432

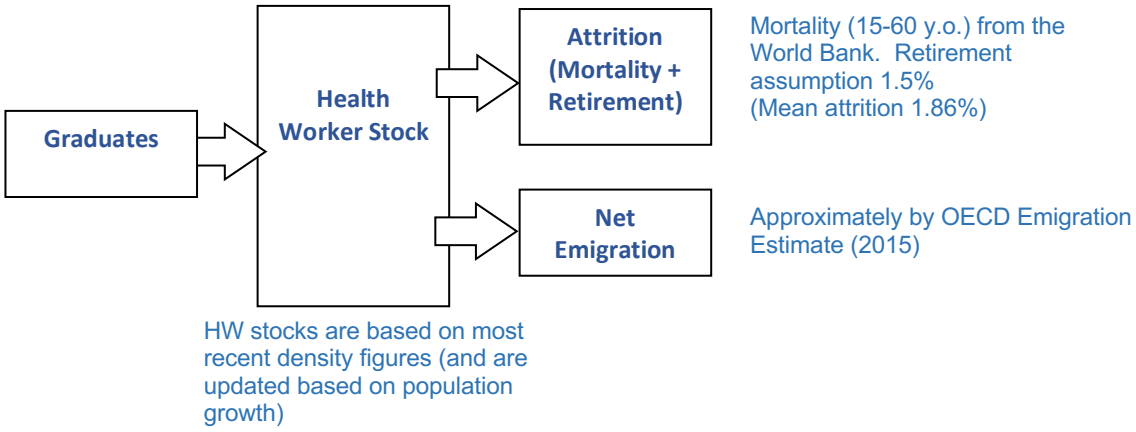
	Tunisia	183
	Turkmenistan	305
	Uganda	12,395
	Ukraine	15,811
	Uruguay	305
	Uzbekistan	3,199
	Yemen, Rep.	247
	Zambia	2,712
	Zimbabwe	1,346
WHO Resilient and people-centered health systems: Progress, challenges, and future directions in Asia.[59]	Philippines	31,379
World Bank-HNP Discussion Paper[60]	Indonesia	50,016
Oxford Business Group, Weill Medical Qatar Annual Report 2018[57-58]	Qatar	13

'Indirect' Annual Graduate Estimates

In cases where no direct estimate exists, a 'stock-based estimate' (SBE) of the required production to maintain the 2018 density of physicians or nurse/midwives is estimated for each country (after accounting for expatriation and attrition). Attrition is a function of country-specific annual mortality probability during working years (proxied by age 15-60 mortality rates), likelihood of retirement (assumed to be ~1.5% per year less the mortality probability for the 'retiring' subset). The estimate also accounts for the expatriation rate of country-born physicians or nurses. Workforce, Mortality Rates, Population (and Population Growth) are sources from World Bank World Development Indicators.[61] Expatriation rates (by birth country, separately for physician and nurses) are proxied by emigration to OECD countries.[62]

Lastly, unlike the prior 2010 estimate, we account for the population growth rate (assuming states aim to at least maintain the physicians or nurse density), not just total number of physicians or nurses, in their country.

Figure 3: Graduate Estimates-SBE Framework



Specifically, when implementing the SBE method, the annual number of graduates for each country were calculated as:

$$\underline{Eq.5 \quad Annual\ Graduates_{c,t}} = \frac{Stock_{c,t} * (Attrition\ Rate_{c,t} + Pop.Growth\ Rate_{c,t})}{(1 - Emigration\ Rate_{c})}$$

where the emigration rate ideally equals the share of domestic-trained health workers who emigrate. The attrition rate has two components A) the probability of death and B) the probability of retirement. WB/WHO adult mortality death (age 15-60) data allows for an estimate of the probability of death at the country specific level (assuming that physicians die at the same rate as adults). The assumption for the probability of retirement will be .015, but we also reduce this by the probability of death during the final year of work (for those unluckily enough to expire upon/just prior to retirement). Specifically,

$$\text{Attrition Rate}_{c,t} = A_{c,t} + (B_{c,t} * (1 - A_{c,t}))$$

$$\text{A=Adult mortality probability}_{c,t} : \text{ Age } 15 - 60$$

B=Estimated rate of retirements based on 50 years service (.02)

These stock-based estimates likely yield underestimates for graduate production and overall expenditures for those countries in which the stock of physicians is rapidly growing. SBEs assume a static stock level. In countries with large growing stocks, the differences could be quite pronounced (such as China). In most cases stocks which will be derived from the WHO data there usually is an updated record within the last three years—so it is unlikely stocks will have grown appreciably (along with the expected production of physicians or nurses/midwives based on these stocks for those countries not reporting direct physician or nurse/midwife graduation figures)

Once we have estimates for the production of health workers in each country (either via a directly reported estimate or via SBE), we will sum to calculate estimated global annual production of health workers (physicians and nurses/midwives). Each country level production estimate will also naturally be used to calculate total educational expenditures (by country and health worker type). All calculations will be conducted in Excel or Stata.

Estimating Overall Expenditures

As indicated in Eq. 1, once country-level estimates of graduates and cost per graduate are available for each cadre, we can estimate annual expenditures and sum, either regionally or globally, to generate aggregate annual costs for training.

Table 7: Doctor Expenditure Estimates, by Model

Physician Expenditure Models($US, 2018: Millions)								
		Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Model Characteristics	Regression Sample	All (n=56)	Econ (n=15)	Econ (n=15)	All (n=56)	All (n=56)	All (n=56)	All (n=56)
	Substitution?	Yes	Yes	No	No	Yes	No	Yes
	Regression Covariate(s)	Income, Region*	Income	Income	Income	Income	Income Band, Region	Income Band, Region
Expenditure by Region	China	$3,429	$3,429	$7,641	$6,113	$3,429	$10,449	$3,429
	India	$8,929	$8,929	$9,702	$7,663	$8,929	$7,574	$8,929
	Other Asia	$2,499	$2,932	$3,334	$2,637	$2,499	$3,556	$3,177
	Central Asia	$774	$977	$977	$774	$774	$954	$954
	Asia Pacific High Income	$4,523	$4,933	$4,761	$4,069	$4,523	$6,299	$5,928
	Europe Central	$812	$912	$1,061	$857	$812	$1,724	$1,126
	Europe Eastern	$2,119	$2,640	$2,640	$2,119	$2,119	$2,848	$2,848
	Europe Western	$12,174	$13,368	$14,012	$11,984	$12,174	$12,014	$12,695
	North America	$13,512	$13,512	$10,828	$9,533	$13,512	$14,095	$13,512
	LAC	$4,330	$4,991	$5,182	$4,146	$4,330	$6,967	$7,059
	MENA	$6,857	$5,436	$5,440	$4,540	$4,671	$6,111	$5,766
	SSA	$593	$851	$1,397	$1,103	$734	$717	$525
	Total	**$60,551**	**$62,909**	**$66,973**	**$55,537**	**$58,506**	**$73,308**	**$65,948**

*In Model 1, the regression results using income as a covariate are generally relied on, but in two regions (SSA and MENA) where the regression that included both income and region were a better, we rely on the estimates from that region.

Table 7 summarizes annual training expenditures across seven different model variants for physicians. Three key variables are adjusted. First, we can use either the full sample (n=56 studies) or a subsample (just economic studies,

n=15) for the costing regression that is used to estimate costs. Second, we can either rely only on the regression for ALL country cost estimates OR substitute the direct estimate for countries where they exist (This choice seems to have the most influence in China). Lastly, the regressions that support the cost estimates may differ with respect to the covariates (income per capita, region and/or income band). The model characteristics in Table 7 reflect the choices made for each of the models. Table 8 shows the same results for Nurses. Model 1 is the 'lead' model and generally appears to fall in the middle of the range at the global level.

Table 8: Doctor Expenditure Estimates, by Model

Nurse Expenditure Models($US, 2018: Millions)								
		Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Model Characteristics	Regression Sample	All (n=56)	Econ (n=15)	Econ (n=15)	All (n=56)	All (n=56)	All (n=56)	All (n=56)
	Substitution?	Yes	Yes	No	No	Yes	No	Yes
	Regression Covariate(s)	Income, Region*	Income	Income	Income	Income	Income Band, Region	Income Band, Region
Expenditure by Region	China	$816	$816	$1,818	$1,455	$816	$2,487	$816
	India	$4,509	$4,509	$4,900	$3,870	$4,509	$3,825	$4,509
	Other Asia	$1,748	$1,992	$2,123	$1,681	$1,748	$2,680	$2,591
	Central Asia	$393	$495	$495	$393	$393	$417	$417
	Asia Pacific High Income	$5,548	$6,244	$6,277	$5,341	$5,548	$8,442	$8,150
	Europe Central	$317	$366	$410	$332	$317	$685	$519
	Europe Eastern	$280	$352	$352	$280	$280	$268	$268
	Europe Western	$7,973	$8,664	$9,120	$7,843	$7,973	$7,228	$7,817
	North America	$21,390	$21,390	$17,118	$15,072	$21,390	$22,226	$21,390
	LAC	$2,004	$2,202	$2,290	$1,831	$2,004	$2,535	$2,662
	MENA	$3,165	$2,279	$2,280	$1,864	$1,910	$2,986	$2,867
	SSA	$611	$757	$1,335	$1,054	$691	$668	$582
	Total	**$48,754**	**$50,066**	**$48,517**	**$41,016**	**$47,580**	**$54,447**	**$52,590**

*In Model 1, the regression results using income as a covariate are generally relied on, but in two regions (SSA and MENA) where the regression that included both income and region were a better, we rely on the estimates from that region.

Tables 9 and 10 offer overall updates to the 2010 Commission Report (Tables 1 and 2 in the report) based on our production and expenditure results (Model 1 is used as the base case expenditure model for these tables). Similar to graduate data, health workforce numbers were available and obtained from WHO Health Workforce Portal which were cross-referenced with the OECD database. Health workforce is defined using the International Standard of Classification of Occupations 8th revisions (ISCO-08) from the International Labor Organization.[63] The following categories were used to estimate the health workforce totals in Table 9.

> Doctors: 2211 (general medical practitioners), 2212 (specialist medical practitioner), and medical practitioners not further defined as general or specialist.
>
> The sum of 'Nurses' and 'Midwives' is used to estimate the total nurse/midwife category.
> Nurses: 2221 (nursing professionals), 3221 (nursing associate professionals), and nursing personnel not further defined by respective countries as professional or associate.
> Midwifery personnel: 2222 (midwifery professionals), 3222 (midwifery associate professionals) and midwifery personnel not further defined by respective countries as professional or associate.

Although the 2010 Lancet Commission report covered medical, nursing, and public health schools, we were only able to update medical and public health schools. Medical school numbers were available and obtained from the World Directory of Medical Schools.[64] The World Directory defines a "medical school" as an educational institution that provides a complete or full program of instruction leading to a basic medical qualification; that is, a qualification that permits the holder to obtain a license to practice as a medical doctor or physician. Figure 4 depicts number of private and public medical schools by year.

Public health schools were available and obtained from the following sources: Association of Schools of Public Health in Africa,[65] Latin American and Caribbean Association of Public Health Education,[66] Council of Education on Public Health,[67] Asia-Pacific Academic Consortium for Public Health,[68] and the Association of School of Public Health in the European Region.[69] Nursing schools lacked comparable international databases and the availability and content of national statistics varied greatly.

We could not find a global goal for professional nurses-to-population. We found per country ratios but could not determine their means and ranges of existing nor ideal global ratios. There is no established standard for countries to use as a benchmark as they establish educational and practice goals.

Table 9: Production and Workforce (by Region)

	Population Mill. (2018)	2018 Est. Graduates per Year (1000s)		2018 Workforce (1000s)		Est. Number of Schools (2018)		% Medical School Private (2018)
		Doctors	Nurses/ MWs	Doctors	Nurses/ MWs	Public Health	Medical	
Asia								
China	1,393	93	99	2,767	3,721	153	157	1.9%
India	1,353	128	323	1,171	2,360	60	457	52.1%
Other	1,141	46	155	879	2,195	65	488	53.5%
Central	89	12	31	275	723	3	71	35.2
High Income Asia Pacific	250	20	143	565	2,354	54	161	42.2%
Europe								
Central	82	10	19	223	525	17	72	12.5%
Eastern	209	28	21	806	1,705	9	124	6.5%
Western	436	60	180	1,644	4,328	70	283	9.5%
America								
North America	364	29	227	955	5,149	99	212	44.8%
LAC	638	56	126	1,454	3,263	80	776	58.1%
Africa/Middle East								
MENA	533	41	106	767	1,403	51	330	19.7%
SSA	1,099	18	89	246	1,072	62	253	24.9%
World	7,585	542	1,518	11,752	28,798	723	3,384	38.8%

Figure 4: Number of new public and private medical schools by year

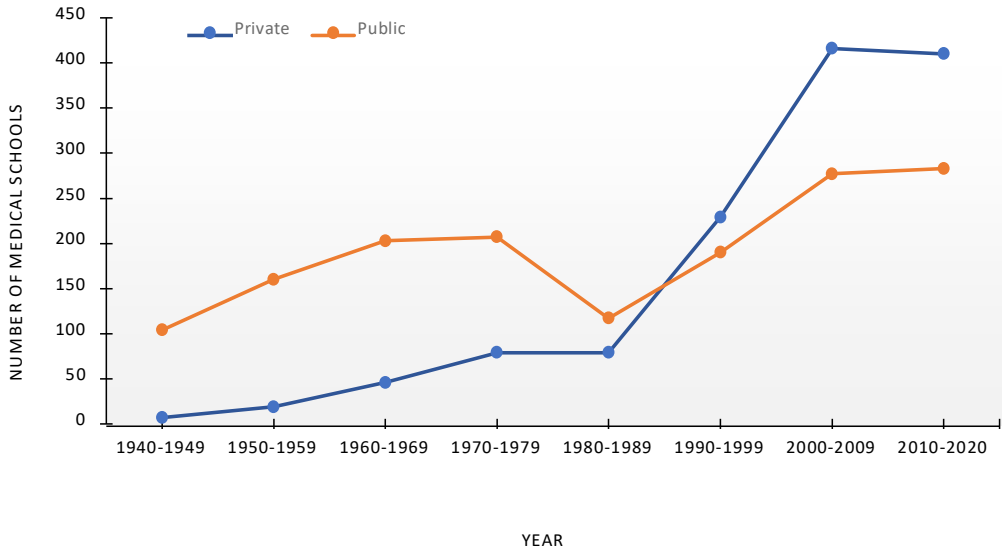


Table 10: Production and Expenditures (by Region)

	2018 Est. Graduates per Year (1000s)		2018 Est. Expenditures per Graduate ($US 1000s)		2018 Est. Total Expenditures ($US Billions)	
	Doctors	Nurses/ MWs	Doctors	Nurses/ MWs	Doctors	Nurses/ MWs
Asia						
China	93	99	41	8	3.8	0.8
India	128	323	70	14	8.9	4.5
Other	46	155	54	11	*2.5*	1.7
Central	12	31	63	13	0.8	0.4
High Income Asia Pacific	20	143	223	39	4.5	5.5
Europe						
Central	10	19	80	17	0.8	0.3
Eastern	28	21	77	13	2.1	0.3
Western	60	180	204	44	12.2	8.0
America						
North America	29	227	469	94	13.5	21.4
LAC	56	126	77	16	4.3	2.0
Africa/Middle East						
MENA	41	106	166	30	6.9	3.2
SSA	18	89	32	7	0.6	0.6
World	542	1,518	112	32	60.9	48.8

Lastly Table 11 lists which countries are categorized in each region for the 2018 analysis.

Table 11: Country Mapping for Regions

World Bank Country Code	Country	Study Region Code	Study Region
CHN	China	1	China
IND	India	2	India
AFG	Afghanistan	3	Other Asia
BGD	Bangladesh	3	Other Asia
BTN	Bhutan	3	Other Asia
IDN	Indonesia	3	Other Asia
KHM	Cambodia	3	Other Asia
LAO	Lao PDR	3	Other Asia
LKA	Sri Lanka	3	Other Asia
MDV	Maldives	3	Other Asia
MMR	Myanmar	3	Other Asia
MNG	Mongolia	3	Other Asia
MUS	Mauritius	3	Other Asia
MYS	Malaysia	3	Other Asia
NPL	Nepal	3	Other Asia
PAK	Pakistan	3	Other Asia
PHL	Philippines	3	Other Asia
PRK	Korea, Dem. People's Rep.	3	Other Asia
THA	Thailand	3	Other Asia
TLS	Timor-Leste	3	Other Asia
VNM	Vietnam	3	Other Asia

ARM	Armenia	4	Central Asia
AZE	Azerbaijan	4	Central Asia
GEO	Georgia	4	Central Asia
KAZ	Kazakhstan	4	Central Asia
KGZ	Kyrgyz Republic	4	Central Asia
TJK	Tajikistan	4	Central Asia
TKM	Turkmenistan	4	Central Asia
UZB	Uzbekistan	4	Central Asia
ASM	American Samoa	5	Asia Pac High Inc
AUS	Australia	5	Asia Pac High Inc
BRN	Brunei Darussalam	5	Asia Pac High Inc
FJI	Fiji	5	Asia Pac High Inc
FSM	Micronesia, Fed. Sts.	5	Asia Pac High Inc
HKG	China: Hong Kong SAR	5	Asia Pac High Inc
JPN	Japan	5	Asia Pac High Inc
KIR	Kiribati	5	Asia Pac High Inc
KOR	Korea, Rep.	5	Asia Pac High Inc
MAC	China: Macao SAR	5	Asia Pac High Inc
MHL	Marshall Islands	5	Asia Pac High Inc
NCL	New Caledonia	5	Asia Pac High Inc
NRU	Nauru	5	Asia Pac High Inc
NZL	New Zealand	5	Asia Pac High Inc
PLW	Palau	5	Asia Pac High Inc
PNG	Papua New Guinea	5	Asia Pac High Inc
PYF	French Polynesia	5	Asia Pac High Inc
SGP	Singapore	5	Asia Pac High Inc
SLB	Solomon Islands	5	Asia Pac High Inc
TON	Tonga	5	Asia Pac High Inc
TUV	Tuvalu	5	Other Asia
VUT	Vanuatu	5	Asia Pac High Inc
WSM	Samoa	5	Asia Pac High Inc
ALB	Albania	6	Europe Central
BGR	Bulgaria	6	Europe Central
BIH	Bosnia and Herzegovina	6	Europe Central
HRV	Croatia	6	Europe Central
HUN	Hungary	6	Europe Central
MNE	Montenegro	6	Europe Central
POL	Poland	6	Europe Central
ROU	Romania	6	Europe Central

SRB	Serbia	6	Europe Central
SVK	Slovak Republic	6	Europe Central
SVN	Slovenia	6	Europe Central
XKX	Kosovo	6	Europe Central
BLR	Belarus	7	Europe Eastern
EST	Estonia	7	Europe Eastern
LTU	Lithuania	7	Europe Eastern
LVA	Latvia	7	Europe Eastern
MDA	Moldova	7	Europe Eastern
MKD	North Macedonia	7	Europe Eastern
RUS	Russian Federation	7	Europe Eastern
UKR	Ukraine	7	Europe Eastern
AND	Andorra	8	Europe Western
AUT	Austria	8	Europe Western
BEL	Belgium	8	Europe Western
CHE	Switzerland	8	Europe Western
CHI	Channel Islands	8	Europe Western
CYP	Cyprus	8	Europe Western
CZE	Czech Republic	8	Europe Western
DEU	Germany	8	Europe Western
DNK	Denmark	8	Europe Western
ESP	Spain	8	Europe Western
FIN	Finland	8	Europe Western
FRA	France	8	Europe Western
FRO	Faroe Islands	8	Europe Western
GBR	United Kingdom	8	Europe Western
GIB	Gibraltar	8	Europe Western
GRC	Greece	8	Europe Western
GRL	Greenland	8	Europe Western
GUM	Guam	8	Europe Western
IMN	Isle of Man	8	Europe Western
IRL	Ireland	8	Europe Western
ISL	Iceland	8	Europe Western
ITA	Italy	8	Europe Western
LIE	Liechtenstein	8	Europe Western
LUX	Luxembourg	8	Europe Western
MCO	Monaco	8	Europe Western
MLT	Malta	8	Europe Western
NLD	Netherlands	8	Europe Western

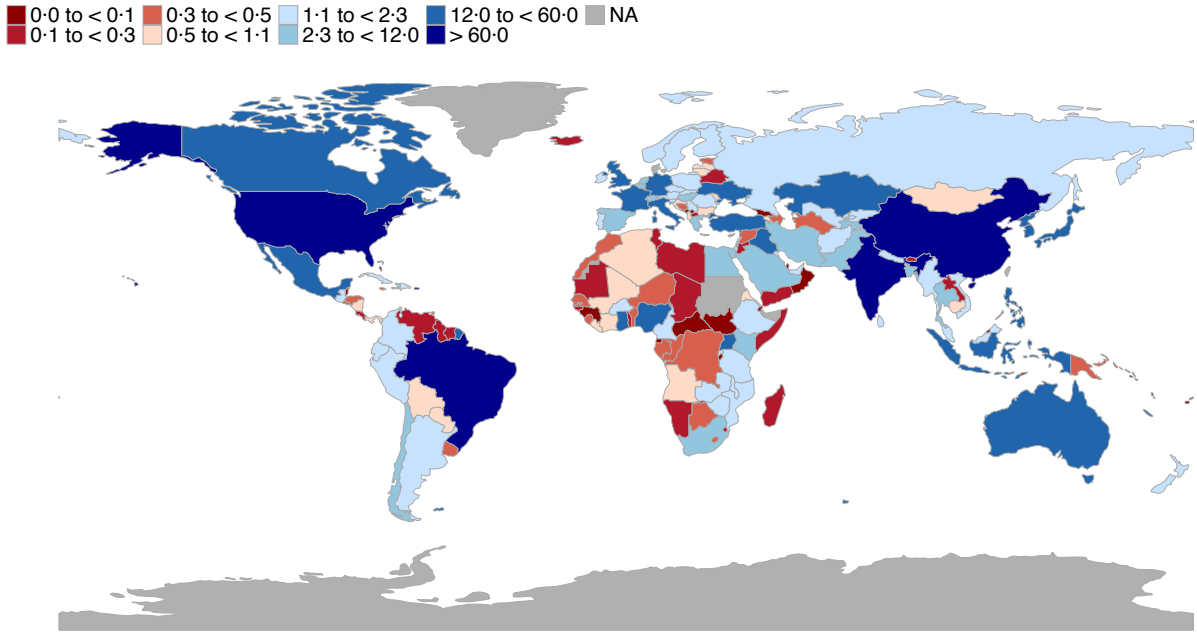
NOR	Norway	8	Europe Western
PRT	Portugal	8	Europe Western
SMR	San Marino	8	Europe Western
SWE	Sweden	8	Europe Western
CAN	Canada	9	North America
USA	United States	9	North America
ABW	Aruba	10	LAC
ARG	Argentina	10	LAC
ATG	Antigua and Barbuda	10	LAC
BHS	Bahamas	10	LAC
BLZ	Belize	10	LAC
BMU	Bermuda	10	LAC
BOL	Bolivia	10	LAC
BRA	Brazil	10	LAC
BRB	Barbados	10	LAC
BVG	British Virgin Islands	10	LAC
CHL	Chile	10	LAC
COL	Colombia	10	LAC
CRI	Costa Rica	10	LAC
CUB	Cuba	10	LAC
CUW	Curacao	10	LAC
CYM	Cayman Islands	10	LAC
DMA	Dominica	10	LAC
DOM	Dominican Republic	10	LAC
ECU	Ecuador	10	LAC
GRD	Grenada	10	LAC
GTM	Guatemala	10	LAC
GUY	Guyana	10	LAC
HND	Honduras	10	LAC
HTI	Haiti	10	LAC
JAM	Jamaica	10	LAC
KNA	St. Kitts and Nevis	10	LAC
LCA	St. Lucia	10	LAC
MAF	St. Martin (French part)	10	LAC
MEX	Mexico	10	LAC
NIC	Nicaragua	10	LAC
PAN	Panama	10	LAC
PER	Peru	10	LAC
PRI	Puerto Rico	10	LAC

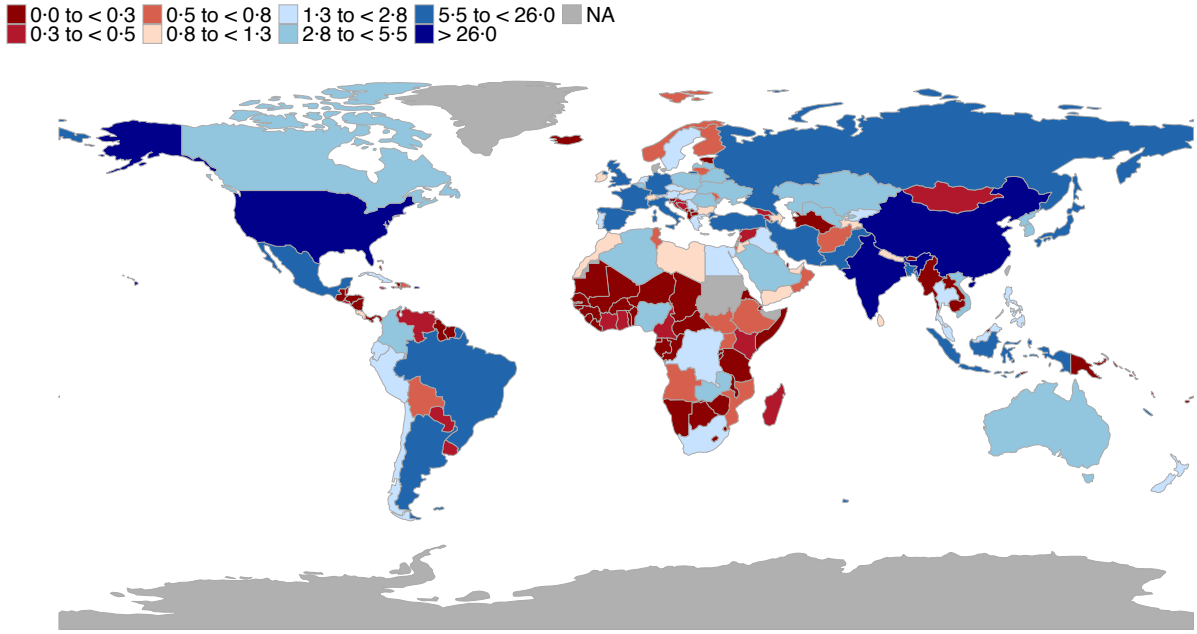
PRY	Paraguay	10	LAC
SLV	El Salvador	10	LAC
SUR	Suriname	10	LAC
SXM	Sint Maarten (Dutch part)	10	LAC
TCA	Turks and Caicos Islands	10	LAC
TTO	Trinidad and Tobago	10	LAC
URY	Uruguay	10	LAC
VCT	St. Vincent and the Grenadines	10	LAC
VEN	Venezuela, RB	10	LAC
VIR	Virgin Islands (U.S.)	10	LAC
ARE	United Arab Emirates	11	MENA
BHR	Bahrain	11	MENA
DZA	Algeria	11	MENA
EGY	Egypt, Arab Rep.	11	MENA
IRN	Iran, Islamic Rep.	11	MENA
IRQ	Iraq	11	MENA
ISR	Israel	11	MENA
JOR	Jordan	11	MENA
KWT	Kuwait	11	MENA
LBN	Lebanon	11	MENA
LBY	Libya	11	MENA
MAR	Morocco	11	MENA
OMN	Oman	11	MENA
PSE	West Bank and Gaza	11	MENA
QAT	Qatar	11	MENA
SAU	Saudi Arabia	11	MENA
SYR	Syrian Arab Republic	11	MENA
TUN	Tunisia	11	MENA
TUR	Turkey	11	MENA
YEM	Yemen, Rep.	11	MENA
AGO	Angola	12	SSA
BDI	Burundi	12	SSA
BEN	Benin	12	SSA
BFA	Burkina Faso	12	SSA
BWA	Botswana	12	SSA
CAF	Central African Republic	12	SSA
CIV	Cote d'Ivoire	12	SSA
CMR	Cameroon	12	SSA
COD	Congo, Dem. Rep.	12	SSA

COG	Congo, Rep.	12	SSA
COM	Comoros	12	SSA
CPV	Cabo Verde	12	SSA
DJI	Djibouti	12	SSA
ERI	Eritrea	12	SSA
ETH	Ethiopia	12	SSA
GAB	Gabon	12	SSA
GHA	Ghana	12	SSA
GIN	Guinea	12	SSA
GMB	Gambia, The	12	SSA
GNB	Guinea-Bissau	12	SSA
GNQ	Equatorial Guinea	12	SSA
KEN	Kenya	12	SSA
LBR	Liberia	12	SSA
LSO	Lesotho	12	SSA
MDG	Madagascar	12	SSA
MLI	Mali	12	SSA
MOZ	Mozambique	12	SSA
MRT	Mauritania	12	SSA
MWI	Malawi	12	SSA
NAM	Namibia	12	SSA
NER	Niger	12	SSA
NGA	Nigeria	12	SSA
RWA	Rwanda	12	SSA
SDN	Sudan	12	SSA
SEN	Senegal	12	SSA
SLE	Sierra Leone	12	SSA
SOM	Somalia	12	SSA
SSD	South Sudan	12	SSA
STP	Sao Tome and Principe	12	SSA
SWZ	Eswatini	12	SSA
SYC	Seychelles	12	SSA
TCD	Chad	12	SSA
TGO	Togo	12	SSA
TZA	Tanzania	12	SSA
UGA	Uganda	12	SSA
ZAF	South Africa	12	SSA
ZMB	Zambia	12	SSA
ZWE	Zimbabwe	12	SSA

Global Maps
Global maps were created using RStudio (version 4.1.1).

Figure 1. Density of nursing (top) and medical graduates (bottom) per 1,000 population by country (2018)





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Annex 2: Citation Analysis and Literature Review

Methodology: Literature Review of Publication Citing the 2010 Lancet Commission Report

Selection of Citation Databases

To develop the sampling methodology, we consulted two research librarians at University of Miami. We first identified appropriate research databases from which to obtain publications citing the 2010 Lancet report. When investigating their accuracy and appropriateness, we used the results of a comparison conducted by Falages et al. (2007)[1] who assessed different research database tools for factors including, but not limited to their extent of journal and field coverage, frequency of literature updates, and the presence of bias in search results.

Four databases were considered. The number of publications citing the 2010 Lancet Commission report[2] were identified in each database by searching the report's title: *Health professionals for a new century: transforming education to strengthen health systems in an interdependent world*. At the time, *Scopus* reported 1,991 citing publications, *Web of Science (WoS) Core Collection*, 1,327, *PubMed*, 638, and *Google Scholar*, 4,070. Table 1 compares the strengths and weaknesses across each database.[1] *Web of Science* and *Scopus* were selected for this review. Both indexed a large number of journals, 8,700 and 12,850, respectively, and covered content from most scientific fields compared to *PubMed* and *Google Scholar*. Scopus is an ideal research tool for extracting medical and academic literature and WoS is ideal for evaluating the importance and influence of specific publications (Journal Impact Factor (IF)). These functions were suitable for the aim and scope of this citation analysis. Moreover, *Google Scholar* reported the largest number of citing articles, however, the accuracy of its content coverage is uncertain as this database lacks defined journal coverage and contains frequent duplicates. Additionally, the two selected databases are not biased in their search results whereas *PubMed* and *Google Scholar* tend to produce inconsistent and/or biased results.

Table 1: Research database tools justification

	Research Database Tools			
	Scopus	**Web of Science**	**PubMed**	**Google Scholar**
Journal coverage	12,850 of which 500 are open access Indexes larger number of journals compared to other search engines	8,700; Better journal classification system than Scopus	6,000 of which 827 are open access	Content coverage is unknown / no journal frame and/or list available
Fields	Covers most scientific fields	Covers most scientific fields	Focuses mainly on medicine and biomedical sciences	Covers most scientific fields
Literature updates	Readily updated with printed literature but does not include online early versions	Updated weekly with printed literature but does not include online early versions	Updated daily with printed lit and online early versions before print	Updated monthly on average
Citation Analysis	Faster and produces more articles than web of science	Citation analysis has better graphics and is more detailed than the Scopus	None	The reference list is shorter compared to other databases.
Search Results	No bias with relevant results	No bias with relevant results	Produces newest articles first. Produces results peripheral relevance to the subject and relevance is inconsistent	Produces results that are most cited first. Results are not related to the quality of publication
Other	Enhanced utility, for both medical literature search and academic needs. Results produced by Scopus corresponded to its extended listing of included journals with a greater number of citations. False-positive results in Scopus could	Journal impact factor – a tool for evaluating the importance and influence of specific publications	Handy, quick, and easy to use. Offers over 1 million freely available articles of which a significant number come from digitized back issues	Inadequate Web search that aims to reach the widest audience available. Duplicates were a common occurrence

	be eliminated if one is searching for articles including the keyword in the title only			

Data Searches and Extraction

In September and October 2019, WoS and Scopus databases were searched, respectively, for all articles citing the 2010 Lancet report and published between December 2010 and October 2019. The 2010 Lancet report's title was used as the only key term during these searches: *Health professionals for a new century: transforming education to strengthen health systems in an interdependent worl*d. No language limits were used during the search. Some publications indexed in the Chinese Citation Database and Book Citation Index could not be extracted from WoS. To increase the possibility to find the missing book chapters, books, and other citing articles, we relied on Scopus database searches.

As recommended by the research librarians, EndNote X9 was used as a practical reference management software. A total of 3,240 publications were imported into EndNote from WoS (N = 1,249) and Scopus (N = 1,991). 1,076 duplicate references were removed from the complete reference library in EndNote. 30-40% of the PDFs were automatically imported into EndNote. Missing PDFs were manually obtained through various citation databases or interlibrary loan requests.

Citation Review and Classification

The complete reference library of 2,164 unduplicated citations were randomized in Microsoft Excel and grouped into sets of 100. Given the timeline, it was not practical to review the entire citation library, therefore, 1,000 were blindly reviewed by three reviewers. The literature review methodology was reviewed and vetted by sampling experts from the University of Miami Library and deemed robust thereby justifying our decision to stop the randomized review at 1,000 citations. The citations were screened for eligibility (Table 2) and classified based on Level 1-3 criteria (Table 3). One or more of each level criteria must be met for a reviewer to classify as either Level 1, 2 or 3. Microsoft Excel was used to record results of citations analyses and classification. When level classifications were discordant between two reviewers, third reviewer acted as the tiebreaker.

Table 2: Inclusion/Exclusion Criteria

Inclusion Criteria:

1. Referenced 2010 Lancet report
2. Published between December 2010 and October 2019
3. Articles and book chapters written in English

Exclusion Criteria:

1. Non-English publications
2. Full books
3. Publications whose PDFs are not accessible by the library

*In addition to using the initial inclusion/exclusion criteria, we stablished a secondary set of exclusion criteria as follows:

4. Publications withdrawn from publication
5. Publications without a reference of 2010 Lancet Report
6. Additional duplicates identified in EndNote X9

**Once the review process began, the reviewers identified additional inclusion/exclusion criteria*

Table 3: Citation Review and Classification Criteria

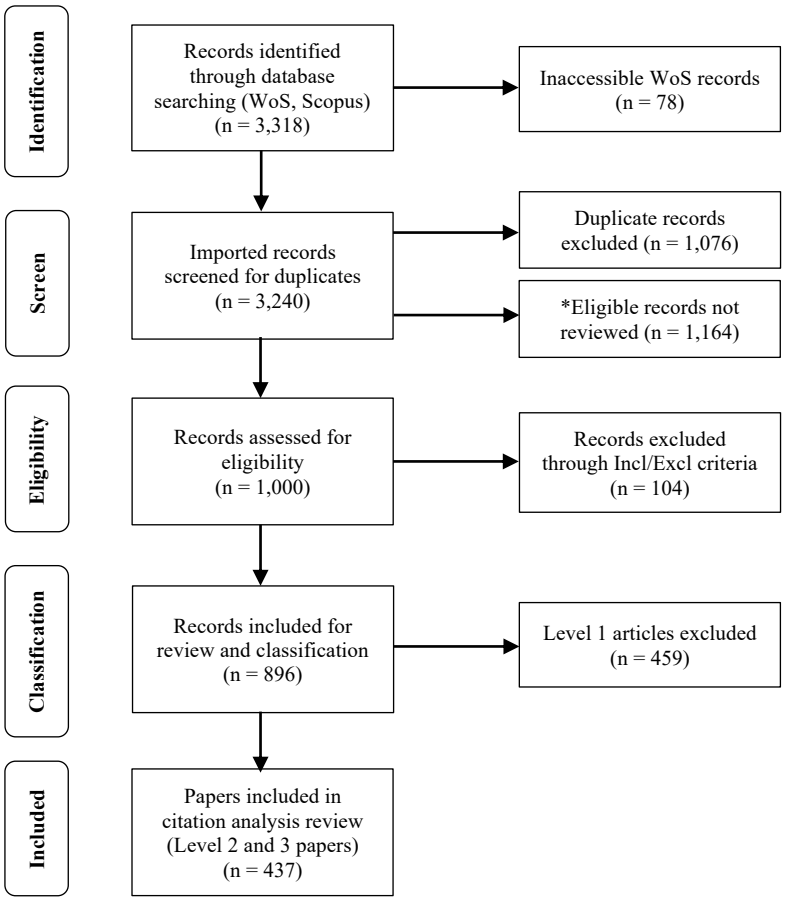
Level 1 Citations: • 2010 Lancet Commission Report cited but no specific point stated OR does not connect to a specific theme in the Lancet report • The *Lancet* Commission or other variant for referencing the 2010 report mentioned in a sentence, but article's focus does not align with the *Lancet* report's reforms or themes • Conducts a literature review of studies or innovations, but does not connect to, align with, or is not inspired by 2010 *Lancet* report • Innovation, models, programs etc. presented were implemented pre-*Lancet* publication
Level 2 Citations: • Echoes or elaborates on one or more themes covered in the *Lancet* report • Aligns with one or more proposed reforms or themes in 2010 *Lancet r*eport, but no new innovation, expansion, framework, model, or novel approach presented or described
Level 3 Citations: • Presents, describes, or justifies an innovation, expansion, framework, model, or novel approach which aligns with one or more proposed reforms or themes in 2010 *Lancet* report • Content is inspired by or grounded upon the 2010 *Lancet* report

Figure 1 outlines the retrospective citation analysis selection process. Of the 896 citations that met the inclusion criteria, 437 were included in the citation analysis review.

Key Theme Analysis

The 437 papers classified as Level 2 or 3 were further reviewed and analyzed to understand the application of the proposed reforms, the diversity of health professions, thematic emphasis, and the geographic distribution of research. The review reveled three most frequently mentioned themes: competency-based education, interprofessional education, and information technology facilitated education. Of the 437 levels 2 and 3 papers, the ones that focused on the respective themes were further examined in depth and included in the synthesis of the key theme analysis.[3-135]

Figure 1: Citation analysis identification, screening, and classification process



*1,164 of 2,164 eligible records were not reviewed considering timeline and a consult from a sampling expert.

Methodology: Literature Review of the Most Prominent Themes Beyond the 2010 Lancet Commission Report
In addition to the review of publications citing the Lancet Commission report, we reviewed a selected number of papers that did not cite report to build upon and inform the citation analysis. We then conduct a high-level overview of the literature highlighting the three key themes (competency-based education, interprofessional education and information technology facilitated education) relevant to health professions education throughout the last decade (2010-2019).

Two bibliographic databases were used:

1. Cumulative Index to Nursing and Allied Health Literature (CINAHL)/EBSCO*host*
2. MEDLINE, the National Library of Medicine's database of life sciences/biomedical articles

The search was conducted among all "health professions education" publications and limited to English language articles published from 2011 through 2019, inclusive. *MEDLINE* and *CINAHL* MeSH terms were used to identify papers relevant to our topics regardless of whether they cited the Lancet Commissioner. Over 10,000 publications were identified. Using Digital Object Identifiers (DOI) and Unique Identifiers (UI), the identified papers were imported into *Web of Science Core Collection* because both *MEDLINE* and *CINAHL* do not have sufficient citation analysis capabilities. Once in *Web of Science Core Collection,* we applied inclusion/exclusion criteria to further narrow down the number of publications.

Tables 4: Inclusion/exclusion criteria

Include	Exclude
1. Articles, reviews 2. Abstract available, 2011-19, English 3. Published in the *WOS* Science Citation Index (SCI) - Expanded	1. Editorials, letters, proceedings, individual/personal descriptive accounts, case studies, webinars, conference, symposium write-ups 2. No abstract

Over 5,000 records satisfied the inclusion criteria (Figure 2). Due to this high volume of papers, we selected 50 most cited publications for each theme (competency-based education, interprofessional education and collaborative practice, and information technology), 150 in total and exported them out for review.

Limitations with this approach:

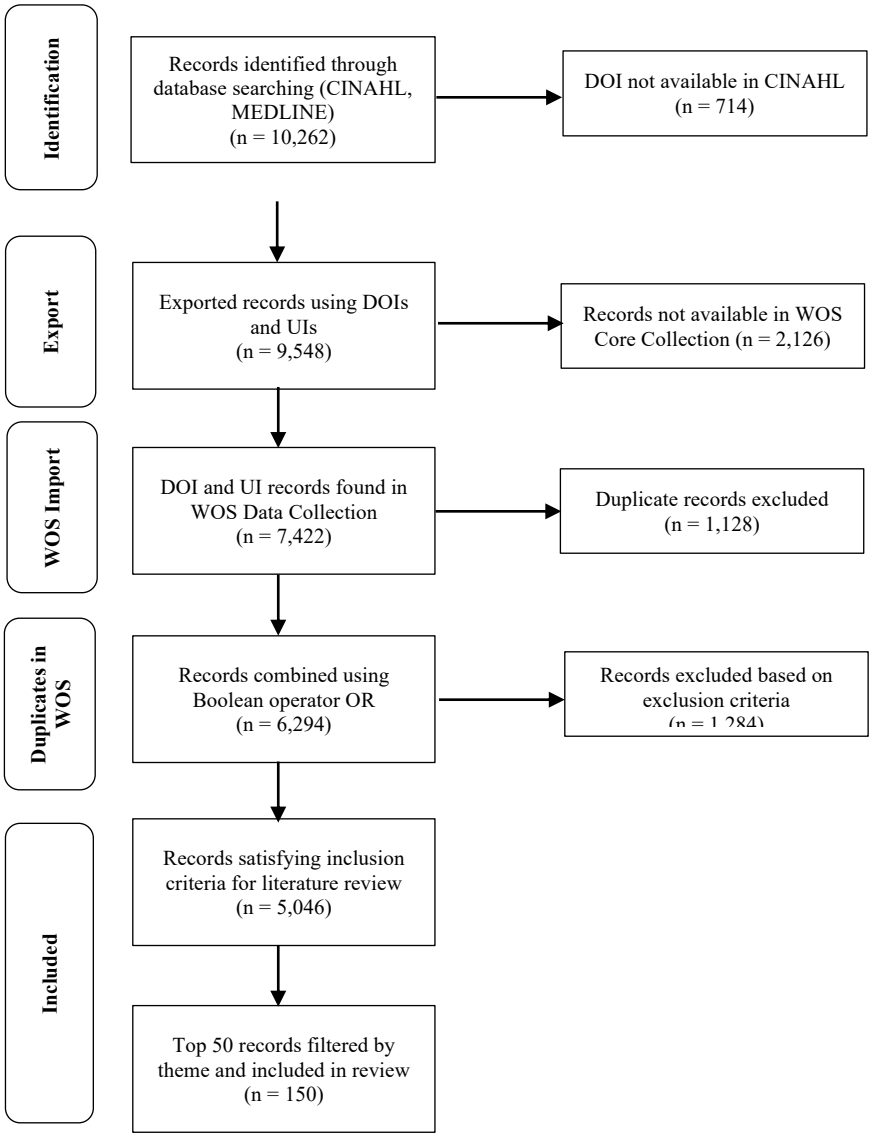
a) Recently published articles tended to have been cited fewer times due to the limited time since publication.
b) The 150 selected articles may not cover all of the topics found in the citation analysis.

We used a similar classification approach (Table 5) from the citation analysis to select the most relevant publications. Of the 150 papers, Level 2 or 3 papers were further analyzed for inclusion in our results.[136-194]

Table 5: Classification criteria

Level 1 publications: • Descriptive and/or presents a relatively minor point • Publication is too specific (e.g., Plastic surgery) • Publication reviews literature published before 2010
Level 2 publications: • Profound conceptualization of competency-based education (CBE), interprofessional education/collaborative practice (IPECP), or information technology (IT)/online learning that aligns with the general idea presented in the 2010 report • Does not cite the 2010 Lancet report
Level 3 publications: • Description of a comprehensive reform or application that aligns with the CBE, IPECP, or IT as presented in the Lancet report • Does not cite the 2010 Lancet report

Figure 2: Literature review identification, screening, and classification process.



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Annex 3: Examples from Literature Review Prior to COVID-19

We provide details of specific examples from the review of the literature prior to COVID-19 that is summarized in Table 3 of the article.

Competency-Based Education

The Association of Pacific Rim Universities Global Health Program
Health professional education is being pushed to adapt to an increasingly interdependent world and rapid transformations in global context. The need for global health curricular content and standard global health training is increasingly recognized. The field has experienced a proliferation of global health education, training programs, and international collaborations. Despite the growing interest, there has been lack of coordination and consensus across health professional programs within and across countries regarding the core global health competencies and teaching methods. Recently, the Pacific Rim Universities (APRU) Global Health Program (GHP) has tried to address this gap.

The GHP is coordinated by the APRU and the University of Southern California (USC) Institute on Inequalities and Global Health. APRU, founded by USC in 1997, is an international, non-profit consortium of 50 research universities in the Pacific Rim ‘‘representing 16 economies, 120,000 faculty members and approximately two million students.”[1] The GHP was launched in 2007 and provides its members with collaborative activities in research, education, policy, and training around key global health issues. The program holds annual conferences with opportunities to initiate research collaborations, share scientific publication, attend trainings, and learn how to provide educational and practicum opportunities for students.[2]

Faced with the need to identify and share guidance on how competency-based education and training in global health can be implemented and supported across institutions with varying resources, the GHP has developed a core set of global health competencies for master-level global health education. After convening an international and multidisciplinary group of thirty stakeholders including faculty, university administrators, students and non-governmental organization workers representing 11 economies, the group identified 19 competencies categorized across five domains and developed a plan for how academic institutions can ensure these competencies are effectively taught.

Global health is interdisciplinary and requires that workers are able to respond to diverse and rapidly changing population needs and emerging global health issues. Therefore “standardizing the minimum requirements for competency in global health across institutions and nations can ensure adequate training of future health global leaders, no matter where they work.”[1]

Interprofessional Education

University of Virginia Center for Interprofessional Collaborations
The University of Virginia Center for Academic Strategic Partnership for Interprofessional Research and Education (UVA Center for ASPIRE) was established in 2013 by the UVA Schools of Nursing and Medicine seeking to bridge the gap between medical and nursing education and prepare all students and clinicians to engage in teamwork and improve health outcomes. In 2019 the center was renamed the University of Virginia Center for Interprofessional Collaborations (CIPC). The center has advanced interprofessional training at undergraduate, graduate, clinical and faculty development levels by integrating IPE into the existing clinical curricula, allowing for “adequate mentorship, faculty development, coordination of activities to meet IPE competencies and appropriate assessment and learner outcomes.” [3]

Most recently, the faculty at the UVA CIPC created the UVA ASPIRE model. This new paradigm is intended for use by faculty and clinician educators to design, implement, assess, and evaluate interprofessional education (IPE) and interprofessional collaborative practice (ICP) experiences. It was created by embedding the Interprofessional Education Collaborative (IPEC) core competencies into three overlapping curricular content areas: practical tools, leadership training and relational factors. [4]

The Center is one of four national sites to host the Train-the-Trainer Interprofessional Faculty Development Program (T3-IFDP), an immersive leadership training program from the National Center for Interprofessional Practice and Education (NCIPE). The program prepares interprofessional teams of faculty and clinicians from across the country to work together to develop IPE initiatives at their own institutions at the undergraduate, graduate, faculty, or clinician level.

Information Technology-facilitated Education

Distance Learning and Continuing Professional Development (CPD)

Haiti Medical Education (HME) Project[5-7]

Between 2011 and 2013 this competency-based continuing medical education (CME) curriculum was developed for physicians in rural Haiti based on the premise of distance learning. Videoconferencing technology was used to connect international experts with rural primary care clinical sites in Haiti, where lectures were delivered to Haitian physicians in real-time. Competency guidelines from the American Academy of Family Physicians (AAFP) and College of Family Physicians Canada (CFPC) were adapted to develop a curriculum. These guidelines were reviewed by both Haitian and North American practitioners to reflect the local needs.

E-learning and Simulation

Augmented Reality Integrated Simulation Education (ARISE)[8]

This project was conducted by Carlson & Gagnon in 2016 to merge the idea of simulation, augmented reality (AR), and game-based situated learning theory for nursing students. Augmented reality is "an enhanced version of reality created with the use of technology." The authors found that students improved learning and critical thinking through the "authentic, engaging experience."[9] It is a new mobile technology that has transitioned from computers to mobile devices and are "more successful than regular desktop learning activities. This application of technology is convenient as it could accommodate nurses whose workplaces encourage them to return to school to obtain higher degrees.

The ARISE platform was developed by David Gagnon from the University of Wisconsin and can be used with iPads and iPhones.[10]

Collaborative Connectivity

E-learning with virtual team-mates for IPE: NYU3T curriculum[11]

When compared to a blended-learning IPE program, virtual IPE programs using virtual teammates were evaluated to be superior in terms of scalability, sustainability, faculty training, workload, and student scheduling. Findings such as this resulted in the development of an innovative interprofessional education curriculum model co-located at the NYU Grossman School of Medicine and the NYU Rory Meyers College of Nursing. The curriculum constitutes web-based learning modules, virtual patients, optional mannequin-based interprofessional simulation, and clinical crossover.

TeleSimulation

During the global pandemic in 2020, the NYU Grossman Schools of Medicine developed a TeleSimulation learning platform which is "a new remote simulation modality using web conferencing technology, coupled with Laerdal mannequin vital signs software."[12] The learners and instructors participate in these simulation activities from remote locations via Zoom.

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Annex 4: The Impact of COVID-19 on IT-Facilitated Learning Across Health Professions Education Worldwide (2020) Survey

Objective
In the context of a global emergency, the aim of this study was to understand the technological applications that have been implemented as a result of the pandemic to facilitate the immediate transfer of instruction online to support remote learning. This research used a brief online survey tool to collect relevant de-identified information from Deans and/ Executive Deans of medical and nursing education institutions worldwide. The research was IRB approved (ID:20201163) – the IRB approval letter can be found on page 45 of this annex.

Methodology
Inclusion/Exclusion Criteria
Inclusion Criteria: Participants included Deans and/ Program Directors of presently accredited medical and nursing schools worldwide (US, Canada, and internationally).

Exclusion Criteria: Deans and/ Program Directors of medical and nursing institutions that lack accreditation.

Age Range: N/A

Research design
Recruitment/Sampling. Due to the nature of this study and the differences in availability of comprehensive lists of medical and nursing schools for the target geographical regions, two different approaches were used for recruiting and sampling participants in the United States, Canada and internationally.

a. For the United States and Canada, a systematic random sampling of member schools listed in the American Association of Medical Colleges (AAMC),[1] the Canadian Association of School of Nursing (CASN),[2] and the American Association of Colleges of Nursing (AACN)[3] was conducted. Up to 95 medical and nursing schools Deans US and Canada were contacted for this study.

b. For other international regions, non-probability convenience or snowball sampling was utilized for participant recruitment and sampling. Recruitment was conducted by contacting key persons in respective countries/regions via email to request assistance with disseminating the survey to relevant individuals (Deans of medical and nursing schools). Because a convenience or snowball sampling technique was used for other international regions, a sample size was not able to be anticipated.

Sample
The target respondents were Deans/Executive Deans of medical and/ nursing education institutions in the following regions: United States, Canada, Asia (specifically, China, and the Association of Southeast Asian Nations), Europe (Spain, Sweden, and England), Africa (Tanzania, Kenya, and Uganda), and Latin America and the Caribbean (Mexico, Brazil, and Costa Rica).

Measurement/Instrumentation
A survey was designed and administered using REDCap. It was anticipated to take the respondents approximately 10 minutes to complete the online survey. The variables being measured in this survey included general information about the participating health profession institution, new strategies due to the pandemic, practical experiences, and attitudes/perceptions about sustainability. These variables were retrieved from a review of relevant literature both citing and not citing the 2010 Lancet report of health professions education worldwide as well as input from the previous commissioners.

The informed consent was presented to participants at the beginning of the online survey. Participants were informed that if they chose to complete the survey, they had automatically indicated they have read the consent and agreed to participate. Otherwise, participants had the option not to complete the survey. There were no risks to the respondents. This was a multisite study where the Reaserch Team gathered de-identified information and all electronic data was stored in computer files that were password protected. Only people who were directly involved

with the project had access to those records. Participants did not receive any compensation for participating in this research study.

Detailed study procedures
Recruitment. For the United States and Canada, a systematic random sampling of member schools listed in the American Association of Medical Colleges (AAMC), the Canadian Association of School of Nursing (CASN), and the American Association of Colleges of Nursing (AACN) was conducted. The email addresses of respective Deans and/ their administrative assistants were identified using the school's website and/ Planning group members' input. Up to 95 Deans were contacted.

Sampling.
- For U.S. medical school section from AAMC database: Started at 5th position in the list and selected every 5th school until 30 schools selected in total.
- For Canadian medical school selection from AAMC database: Started at 2nd position and selected every 3rd school until the end of the list was reached.
- For Canadian nursing school selection from CASN: Started at 2nd position in the list and selected every 3rd school until 30 schools were selected or list ended.
- For U.S. nursing school selection from AACN: Started at 5th position in the list and selected every 5th school until 30 schools selected in total.

For other international regions, convenience or snowball sampling was utilized for participant recruitment and sampling as aforementioned in "Research design."

Data collection. For international participants, excluding Canada, a predetermined email, survey link, and all pertinent material were shared with that community liaisons who have explicitly agreed to assist with dissemination via email. For participants in North America, the survey link was shared via Deans' or administrative assistants' email. The data collection period took approximately 2 months.

Internal validity
Since community liaisons with influence or access to Deans in particular countries within a geographic region were contacted for assistance with survey dissemination, the international findings were skewed. The sampled regions were not representative of all medical and nursing schools worldwide. Additionally, differing sampling methods for North America versus other international regions were used, therefore, comparisons cannot be made between the North American sampling frame and the international ones.

Data analysis
Descriptive statistics were reported for discrete variables and inferential statistics for continuous items.

IRB Approval Letter:

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APPROVAL

November 23, 2020

Roderick King
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On 11/23/2020, the IRB reviewed the following submission:

Type of Review:	Modification / Update
Title of Study:	Ten years after the Lancet Commission on Health Professional Education(HPE): COVID-19 Pandemic
Investigator:	Roderick King
IRB ID:	20201163 (MOD00042854)
Funding:	None
IND, IDE, or HDE:	None
Documents Reviewed:	•Online Survey Consent_Oct 15 (1).docx •Survey Instrument_Measures_ Impact of COVID19_Modified Nov 17.docx

The IRB determined this study meets the criteria for an exemption as described in Federal Regulation 45 CFR 46.104. This determination is effective on 11/23/2020.

NOTE: Translations of IRB approved study documents, including informed consent documents, into languages other than English must be submitted to HSRO for approval prior to use.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

If you plan to conduct this study at JHS, or obtain private, identifiable information from JHS, before conducting any research procedures at JHS, you must:

- **Indicate this intention on the Initial Review Smart Form;**
- **Submit an application to JHS; and**
- **Receive an approval letter from the JHS Clinical Research Review Committee (CRRC).**

If you have any questions regarding this process, please contact the JHS Office of Research at 305-585-7226.

Should you have any questions, please contact: Adriana Robledo, IRB Regulatory Analyst, (phone: 305-243-7135; email: arobledo@med.miami.edu)

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Annex 5: A Comprehensive List of Literature Review About the Effects of COVID-19 Pandemic on Health Education and Practice

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Annex 6: Supplementary Figures

Figure 1: Blend of online and in-person instruction by level of learning