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Special Topic Commentary

Doctoral Graduate Programs in the Pharmaceutical Sciences: An International Survey

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ABSTRACT

This publication represents the first to report global information on characteristics and requirements of doctoral programs in the pharmaceutical sciences in schools/colleges of Pharmacy. Survey responses (140 responses) were received from doctoral programs in 23 countries, with the greatest number of responses obtained from Japan, followed by India and the United States. Program characteristics and requirements, and student and faculty information, including graduate placement, in programs in Asia, North America, Europe, Africa and Australia were compared. Survey responses indicated differences in entrance requirements for doctoral programs with minimum requirements being a bachelor's degree, pharmacy degree or master's degree, including a M.Phil. degree. Programs differed widely in size in all geographical areas, but there was a similar emphasis on core educational learning outcomes (core competencies) and Ph.D. graduation requirements including qualifying examinations, thesis defense with internal and external reviewers and requirements for peer-reviewed publications. Additionally, three-quarters of programs indicated that there was external review of their programs every 2-4 or 5-7 years. Female students and female faculty mentors represented about 50% of students/faculty in programs in most geographical areas. Placement of students after graduation indicated that the highest percentage went into the pharmaceutical industry in Asia (predominantly India) and North America, with a lower percentage in Europe, Africa and Australia.

Introduction

Ph.D. degree, first established at Humboldt University in Germany more than 200 years ago, has the general requirement that students complete a prescribed course of graduate study and successfully defend a thesis/dissertation containing original research.[1] A strong system of doctoral education is necessary for future innovation, discovery and invention. Graduate programs need to produce professionals with the problem-solving, scientific and professional skills, including hypothesis generation, statistical methods and data management, presentation of oral and written scientific information and grantsmanship, necessary for success. This publication provides global information on Ph.D. graduate programs in the pharmaceutical sciences, focusing on the structure and similarities/differences internationally in these Ph.D. graduate programs.

This international survey for Ph.D. programs in the pharmaceutical sciences was developed and supported by the International Pharmaceutical Federation (FIP) and the FIP Board of Pharmaceutical Sciences (BPS); FIP is a global organization that represents over 4 million pharmacists and pharmaceutical scientists globally. While there have been a range of publications addressing doctoral programs in

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the pharmaceutical sciences in the United States,[2-12] this represents the first survey to address international graduate programs. In particular, global information was obtained for program educational learning outcomes (core competencies),[4,8] doctoral program requirements for graduation, and the career choices of doctoral program graduates. Results from the survey are presented including all country information, as well as comparisons by geographical localization by continent. This survey provides information concerning the pharmaceutical sciences workforce, early career training, education and training, and professional development provided by doctoral programs in the pharmaceutical sciences. This publication includes information only on doctoral programs, and a companion paper will review our survey information for master's programs.

Methods

A geographically- and discipline-diverse committee was established with representation from Australia, Asia, Africa, Europe and North America. Survey questions were developed by committee members to address Ph.D. programs available through schools or colleges of pharmacy. For the survey, the committee members broadly defined the pharmaceutical sciences to include programs titled: Pharmaceutical sciences, Pharmacology/Toxicology, Pharmaceutical economics, Health outcomes, Medicinal/pharmaceutical chemistry, Bioinformatics, Molecular and cellular biosciences, Public health, Clinical and translational science/Pharmacy.

Most survey questions were developed as multiple-choice questions but write-in answers were included to provide the opportunity for adding further information/clarification. The draft survey was sent out for review by five FIP academic institutional members and revised based on feedback. The survey was then translated into French, Spanish and Portuguese and disseminated broadly to FIP academic member schools, BPS members and pharmacy/pharmaceutical sciences member organizations, as well as other schools/colleges identified by committee members. Surveys were completed by a variety of faculty members, graduate program directors, assistant and associate deans, and deans of schools/colleges of pharmacy. The surveys were available for two 3-week periods in 2021.

Results

One hundred and forty responses regarding doctoral programs were received from 82 public (45%) and private (55%) universities, encompassing 23 countries (Supplemental Table 1). The greatest number of responses were obtained from Japan, followed by India and the United States. A division by region indicated the greatest number of responses for Ph.D. programs from Asia, followed by North America and then Europe, Africa and Australia (Fig. 1).

The survey results are presented here under the categories: a) General program description, that includes research, course and graduation requirements; b) Program curriculum and graduation requirements, including core educational learning outcomes; c) Student composition of programs, including numbers, gender and graduate student placement; d) Faculty members participating in graduate programs, including numbers and gender; and e) Major challenges of graduate programs. A comparison of the results from the 5 geographical areas, namely Asia, North America, Europe, Africa and Australia is presented for the Ph.D. programs. Australia had a low response rate; further follow up was done by contacting 4 graduate program directors in Australia for discussion of survey questions (listed under acknowledgements). No responses on doctoral programs were received from programs in South America, so no comparisons have been made for that geographical area. There was also further outreach to FIP BPS members to address 2 questions, namely (1) What do you see as the major challenge/threat for doctoral graduate programs in the pharmaceutical sciences? and (2) In your opinion, what is the most important role for FIP and BPS to support graduate education programs in the pharmaceutical sciences? These questions received 6 responses, which were reported in the Results section.

Summary of Global Survey Responses

General Program Description

The minimal educational requirements for admission into Ph.D. programs was B.S. (B.Sc.) for 43% of programs, B.S./B.Sc. Pharmacy or Pharm.D. for 24% of programs and M.S (M.Sc.) for 31% or programs. Most of the programs were full-time or predominantly full-time (84%). The typical length of the program for full time students was generally 4-5 years in length, with 17% of programs indicating a length of 3 years and 5% indicating >5 years. For part-time students, the length of programs was most commonly 4-6 years, with 19% between 3-4 years and 14% >7 years. Seventy-five percent of programs indicated a requirement for external review or accreditation of graduate programs (Table 1).

Program Curriculum and Graduation Requirements

Fifty-eight percent of programs had some didactic course requirement, generally involving 1-5 courses (89%) and about 50% reported a teaching or teaching assistant requirement. Fifty percent of

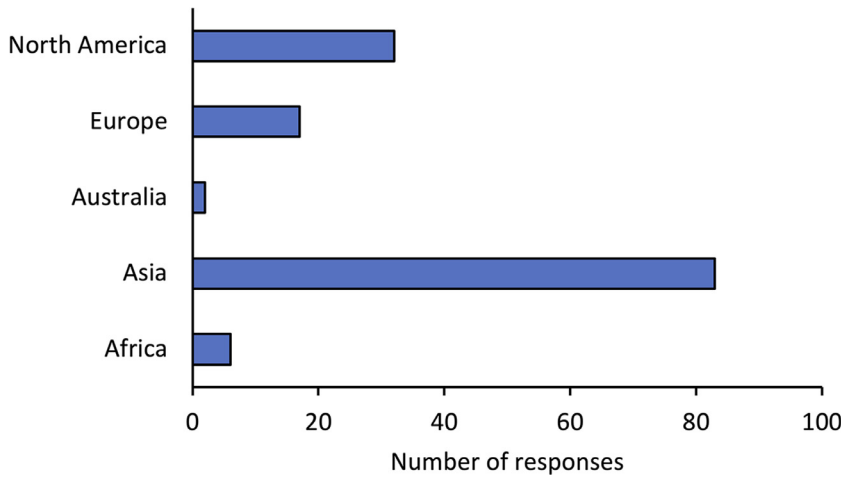

Figure 1. Number of responses for pharmaceutical sciences doctoral programs from different continents.

Table 1
Pharmaceutical Sciences Doctoral Program Characteristics and Geographic Comparison.

What are the minimal educational degree requirements for admission to your program?	All	Asia	Europe	North America	Africa
B.S. (B.Sc.)	43%	29%	35%	84%	33%
B.S./B.Sc. Pharmacy or PharmD	24%	37%	6%	0%	0%
M.Phil	2%	0%	12%	0%	17%
M.S. (M.Sc.)	31%	34%	47%	16%	50%
Number of responses	140	83	17	32	6
Do you have both full-time and part-time students in your program?	**All**	**Asia**	**Europe**	**North America**	**Africa**
Only full-time	55%	56%	29%	81%	0%
Predominantly full-time, with <25% part-time	29%	26%	35%	19%	100%
Full-time with >25% part-time	9%	9%	29%	0%	0%
Predominantly part-time	7%	10%	6%	0%	0%
Number of responses	138	81	17	32	6
What is the typical length of the program for full-time students?	**All**	**Asia**	**Europe**	**North America**	**Africa**
3 years	17%	24%	13%	0%	50%
4 years	52%	68%	50%	16%	50%
5 years	25%	6%	38%	69%	0%
>5 years	6%	3%	0%	16%	0%
Number of responses	128	72	16	32	6
Is there external review or accreditation of your graduate programs?	**All**	**Asia**	**Europe**	**North America**	**Africa**
No	25%	36%	0%	13%	33%
Yes, every 2-4 years	26%	31%	47%	6%	33%
Yes, every 5-7 years	49%	33%	53%	81%	33%
Number of responses	121	67	15	32	6

programs required both a written and oral qualifying (comprehensive) exam, while 22% had no qualifying examination. Ninety-five percent of programs indicated that the programs were research-based, with 5% indicating only exam-based. Of the 95% of programs with a research component, 59% had a thesis requirement and thesis defense with internal and external examiners, and 31% had a thesis requirement and thesis defense with only internal examiners. Seventy-one percent of programs had a requirement of at least one publication prior to graduation. Internships were required in 22% of programs, and an additional 23% stated that internships were not required but many students performed internships (Table 2).

The majority of programs (65-83%) indicated inclusion of core educational learning outcomes, as provided in Table 3) in their curriculum, including research methods and study design, presentation and delivery of oral and written scientific information, literature review and evaluation, ethical conduct of research, statistical methods and data evaluation and hypothesis generation. There was somewhat less emphasis (33-45%) on grantsmanship, teamwork, scientific leadership and management and intellectual property. Sixty-six percent of programs reported presentations on career opportunities.

Student Composition of Programs

The Ph.D. programs ranged in size from <5 to >100 students, with 74% of programs indicating high completion rates (i.e., usually no students leave annually before graduation) (Table 4). International students in Ph.D. programs made up 10-25% of students for 41% of the programs, with 11% indicating >75% of students were international. One-third of programs indicated that 25-50% of students were female while 44% indicated 50-75% of students were female (Fig. 2). When reasons for attrition from the program were questioned and multiple reasons could be listed, the choice of personal/family reasons was listed as the major reason, followed by academic problems (Table 4). Funding of graduate students includes self-funding as well as funding by government/university or as a teaching assistant. Grant support from advisor was listed less prominently compared with these previous sources of funding. Major career placement of students after graduation was the pharmaceutical industry (53%), followed by academia (18%) and postdoctoral fellowships (11%) or community/hospital pharmacy (12%) (Fig. 3A).

Faculty Members Participating in Graduate Education

Forty-nine percent of programs indicated 20-50 faculty members were involved in the program as advisors, with 25% of programs indicating 10-20 faculty members served as advisors. Overall, 14% of programs could be defined as small programs, with 5-10 faculty members, and 12% as large programs, with >50 faculty members. The gender distribution of faculty was of interest with the largest number of programs (42%) indicating 25-50% of faculty advisors were female, with 30% of programs with 10-25% female faculty advisors and 23% of programs with 50-75% female faculty advisors (Table 5).

Major Challenges to Graduate Programs

Responders were asked to choose one major challenge faced by their graduate program. Twenty-five percent indicated decreased faculty funding, followed by 21% with decreased graduate student support, and 19% indicating decreased interest in graduate programs in the pharmaceutical sciences (Table 6). Decreasing career opportunities were indicated by 11%, followed by decreasing pharmacy student enrollment resulting in decreased pharmacy school/college support of graduate programs by 9% (Table 6). When asked to identify the top 3 ways in which FIP could assist with the scientific and professional development of faculty members and graduate students in their

Table 2
Pharmaceutical Sciences Doctoral Program Curriculum and Graduation Requirements.

Are students required to take didactic courses in the program?	All	Asia	Europe	North America	Africa
No	42%	57%	41%	3%	50%
Yes	58%	43%	59%	97%	50%
Number of responses	138	81	17	32	6
Is there a teaching or teaching assistant requirement in your program?	**All**	**Asia**	**Europe**	**North America**	**Africa**
No	49%	39%	56%	63%	83%
Yes	51%	61%	44%	38%	17%
Number of responses	130	74	16	32	6
Is there a requirement for internships in your program?	**All**	**Asia**	**Europe**	**North America**	**Africa**
No	55%	50%	56%	63%	50%
No, but many students perform internships	23%	16%	31%	34%	33%
Yes	22%	34%	13%	3%	17%
Number of responses	130	74	16	32	6
Is there a qualifying (comprehensive) examination?	**All**	**Asia**	**Europe**	**North America**	**Africa**
No	22%	22%	50%	0%	33%
Yes, oral	14%	18%	6%	13%	0%
Yes, written	15%	22%	0%	6%	17%
Yes, written and oral	50%	39%	44%	81%	50%
Number of responses	130	74	16	32	6
Is there a thesis defense?	**All**	**Asia**	**Europe**	**North America**	**Africa**
No, only exam based	5%	7%	0%	0%	17%
Research component and thesis requirement, but no defense	2%	1%	0%	0%	0%
Research component but no thesis requirement	3%	5%	0%	0%	0%
Research component, thesis requirement and thesis defense with external and internal examiners	59%	46%	75%	81%	83%
Research component, thesis requirement and thesis defense with internal examiners	31%	41%	25%	19%	0%
Number of responses	130	74	16	32	6
Is there a requirement for peer-reviewed publication prior to graduation?	**All**	**Asia**	**Europe**	**North America**	**Africa**
Yes, > 3 publications	4%	3%	0%	6%	17%
Yes, 2-3 publications	25%	35%	31%	6%	0%
Yes, one publication	42%	47%	31%	34%	50%
No	29%	15%	38%	53%	33%
Number of responses	130	74	16	32	6

programs, the 2 top choices were professional development programs (46% of choices) and student/faculty international exchange (44%). This was followed by three very close choices (28 or 29%) of student funding for meeting travel, student stipend funding and new faculty grants (Fig. 4).

Comparison of Ph.D. Programs in Asia, Europe, North America, Africa and Australia

Asia (59%), Europe (12%) and North America (23%) accounted for the largest number of Ph.D. programs submitted in this survey from a

Table 3
Core Educational Learning Outcomes in Pharmaceutical Sciences Doctoral Programs.

Does your program address the following areas that have been defined as core educational learning outcomes? (Note: all categories can be chosen)	All	Asia	Europe	North America	Africa
Literature Review and Evaluation	77%	68%	82%	94%	100%
Hypothesis Generation	65%	54%	53%	97%	67%
Research Methods and Study Design	81%	74%	88%	94%	100%
Statistical Methods and Data Evaluation	72%	59%	88%	91%	100%
Grantsmanship	33%	17%	24%	75%	67%
Presentation and Delivery of Oral and Written Scientific Information	83%	76%	77%	100%	100%
Scientific Leadership, Management, and Cross-Disciplinary	45%	39%	59%	59%	17%
Teamwork	44%	43%	53%	44%	50%
Ethical Conduct of Research	72%	60%	82%	91%	100%
Intellectual Property	44%	39%	41%	47%	100%
Other	4%	4%	6%	3%	0%
Number of responses	140	83	17	32	6

Table 4
Student Composition of Pharmaceutical Sciences Doctoral Programs.

How many graduate students were in your program during the last academic year?	All	Asia	Europe	North America	Africa
< 5	11%	12%	6%	16%	0%
5-10	11%	22%	6%	13%	17%
10-25	17%	8%	12%	16%	0%
25-50	10%	16%	0%	6%	0%
50-75	22%	21%	29%	19%	50%
75-100	13%	12%	12%	19%	0%
> 100	16%	10%	35%	13%	33%
Number of responses	140	8	17	32	6
What is the gender distribution of graduate students in your program?	**All**	**Asia**	**Europe**	**North America**	**Africa**
10-25% female students	14%	23%	0%	0%	17%
25-50% female students	33%	36%	24%	22%	67%
50-75 % female students	44%	32%	53%	75%	17%
> 75% female students	9%	9%	24%	3%	0%
Number of responses	132	75	17	32	6
How are graduate students funded (stipend and tuition) while in the program? (Note: Multiple choices could be indicated)	**All**	**Asia**	**Europe**	**North America**	**Africa**
Self-funded	73%	80%	88%	41%	100%
Government	50%	52%	77%	31%	33%
University	47%	39%	53%	63%	50%
Teaching assistant	54%	48%	24%	88%	50%
Grant support of advisor	41%	18%	41%	100%	50%
Pharmaceutical industry support	19%	13%	18%	41%	0%
Number of responses	140	83	17	32	6
What are the reasons for graduate student attrition? (Note: Multiple reasons could be chosen)	**All**	**Asia**	**Europe**	**North America**	**Africa**
Academic problems	35%	29%	47%	47%	33%
Changing programs	20%	8%	12%	47%	67%
Personal/family reasons	67%	63%	65%	75%	83%
Financial problems	29%	37%	35%	0%	50%
Job offer	26%	33%	29%	3%	67%
Number of responses	140	83	17	32	6
Describe the composition of graduate students in your program	**All**	**Asia**	**Europe**	**North America**	**Africa**
10-25% international students	41%	46%	56%	37%	0%
25-50% international students	20%	15%	22%	17%	0%
50-75 % international students	28%	15%	22%	37%	0%
> 75% international students	11%	23%	0%	10%	0%
Number of responses	54	13	9	30	0

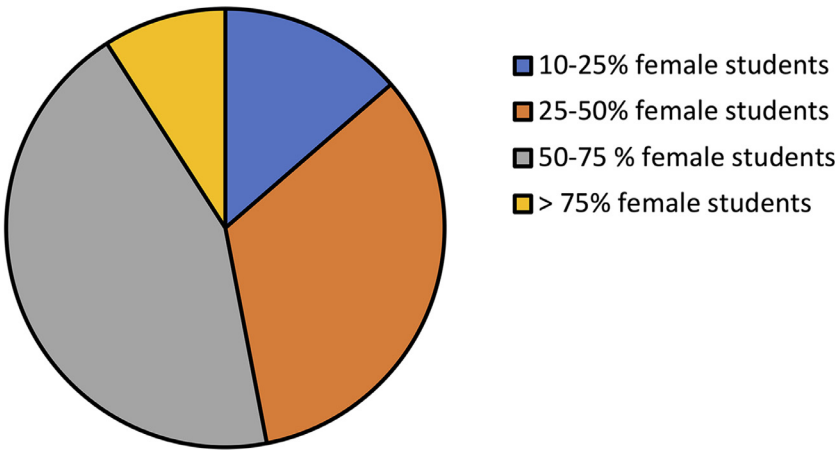

Figure 2. Gender distribution of pharmaceutical sciences doctoral students in the program.

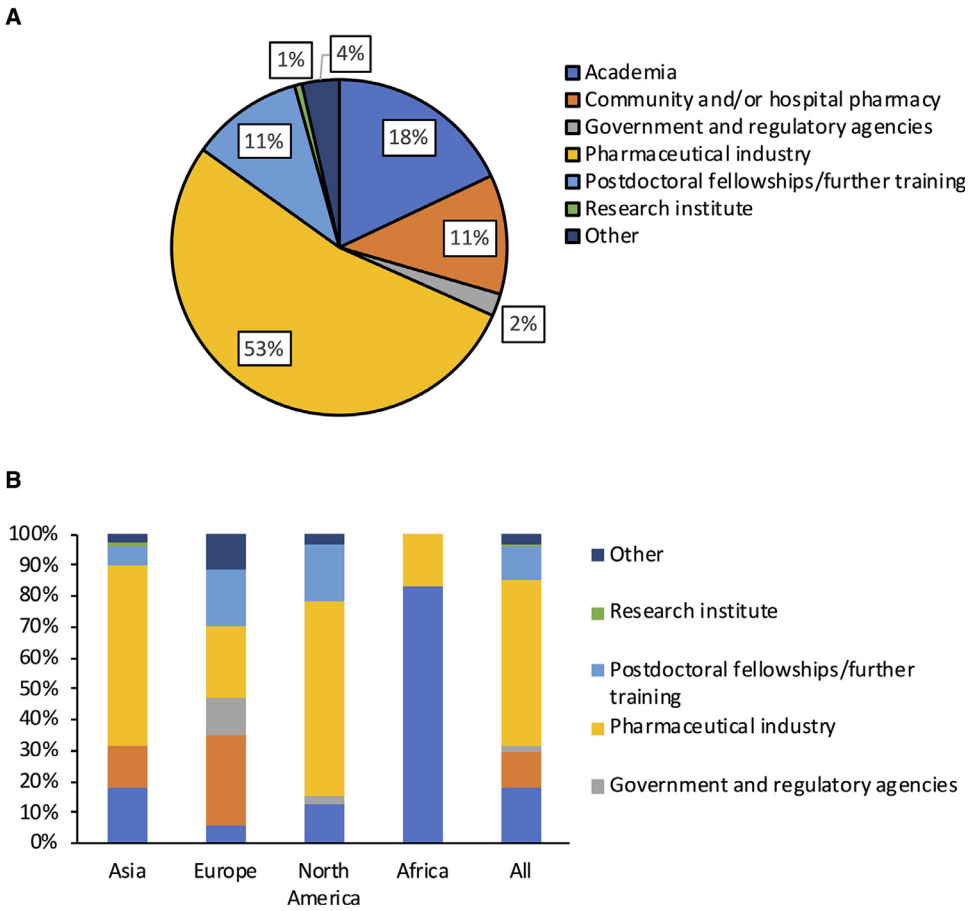

Figure 3. Major career placement for all pharmaceutical sciences doctoral graduates (A) and placement of graduates by continents (B).

total of 140 programs. Ph.D. program information was only received from 6 programs in Africa, 2 in Australia and none in South America; follow-up discussion with 4 graduate program directors in Australia provided additional information. The comparisons below for Asia may be influenced by the high response rates from India and Japan, and further analyses compared programs in India (32 responses) and Japan (38 responses) (Supplemental Table 2, a through g).

Program Description

Minimal entrance requirements differed significantly with 84% of programs in North America indicating B.S. (B.Sc.), compared with 37% of Asian programs requiring a B.S/B.Sc. pharmacy or Pharm.D. and 34% requiring a M.S. (M.Sc.). For European programs 12% required a M. Phil. as the minimal entrance requirement for the program, and 47% required a M.S. (M.Sc.). For the Asian programs, 62.5% of programs in India indicated a B.Sc. Pharmacy or Pharm.D. requirement and 50% of programs in Japan required a master's degree for admission to the program. Australian programs required a B.Sc. degree for admission. Eighty-one percent of programs in North America were only full-time and 100% only or predominantly full-time; this was followed by 83% of Ph.D. programs in Asia being only or predominantly full-time versus 64% of programs in Europe being only or predominantly full-time. The length of the Ph.D. programs in North America

Table 5
Faculty Members Participating in Pharmaceutical Sciences Doctoral Education Programs.

How many faculty members are involved in the program as advisors?	All	Asia	Europe	North America	Africa
5-10	14%	14%	7%	10%	60%
10-20	25%	21%	27%	37%	0%
20-50	49%	55%	47%	40%	40%
>50	12%	9%	20%	13%	0%
Number of responses	108	56	15	30	5
What is the gender distribution of faculty involved in your program?	**All**	**Asia**	**Europe**	**North America**	**Africa**
10-25% female	30%	39%	6%	31%	17%
25-50% female	42%	39%	38%	41%	83%
50-75% female	24%	19%	38%	28%	0%
>75% female	4%	3%	19%	0%	0%
Number of responses	115	59	16	32	6

Table 6
Major challenge/threat Expressed by Pharmaceutical Sciences Doctoral Programs.

	All	Asia	Europe	North America	Africa
Decreasing career opportunities (i.e., students are unemployed after graduation)	11%	19%	0%	0%	17%
Decreasing faculty member funding	25%	17%	13%	40%	50%
Decreasing graduate student support	21%	12%	40%	37%	0%
Decreasing interest in graduate programs in the pharmaceutical sciences	20%	29%	13%	7%	0%
Decreasing Pharmacy student enrollment resulting in decreased graduate program support	9%	8%	7%	10%	33%
Other	14%	15%	27%	7%	0%
Number of responses	118	65	15	30	6

were longer than in Asia and Europe (predominantly >4 years), with 91% of programs in Asia being 3-4 years and 63% in Europe being 3-4 years. Programs in Africa and Australia are also 3-4 years in duration. The majority of programs in all geographical areas required external review of their program. While in Asia, 64% of programs indicated a requirement for external review, this number was higher in India and lower in Japan (Table 1; Supplemental Table 2a).

Program Curriculum and Graduation Requirements

Didactic courses are required in 97% of programs in North America but fewer programs in Africa (50%), Asia (43%) and Europe (59%) (Table 2). In Australia, while some programs have didactic courses, for many programs the courses are elective. More programs in Asia had a teaching assistant requirement and also a requirement for internships than programs in Europe, North America, Africa or Australia. When comparing India and Japan, India had a high requirement for teaching (86%) and internships (71%) while Japan's requirement was much lower. There were large differences in responses regarding the requirement for a qualifying (preliminary, comprehensive) examination for Ph.D. students. No examination was required in 22% of Asian programs, 50% of European programs and 33% of African programs; this contrasted with 100% of programs in North America having the requirement of a qualifying or comprehensive examination. In Asia, 93% of programs were research-based and 83% were research-based in Africa, compared with 100% of programs in Europe and North America. The majority of programs in Europe and North America had the requirement for a thesis defense with internal and external examiners; in Asia, 46% of programs required external and internal examiners, while 41% required only internal examiners. This likely reflects the high percentage of programs in Japan requiring only internal examiners (Supplemental Table 2b). With respect to the requirement for peer-reviewed publications prior to graduation, Australian programs and 53% of North American programs had no requirement, compared to 38% of European programs and 15% of Asian programs (Table 2). Core competencies were similar across all geographical areas (Tables 3 and Supplemental Table 2c).

Student Composition of Programs

Program size varied, but European programs, followed by African programs, had a higher percentage of larger programs (>75 students) and smaller number of small programs (<25 students) than did Asian or North American programs (Table 4). All programs had high percentages of international students in their programs, with somewhat less in European programs. When considering the proportion of females in Ph.D. programs, the responses from Europe (77%) and North America (78%) were similar, indicating >50% of the graduate students were female (Fig. 2). Asian programs indicated 41% had female students representing >50% of graduate students in their programs, with a percentage of 67% in India and 12% in Japan (Supplemental Table 2d). Australian programs indicated that female students comprise 50-75% of all students. Attrition from programs was generally low, with 74% of Ph.D. programs usually indicating none. The reasons for attrition were personal/family problems (64%), followed by academic problems (35%), and financial problems (29%). Financial problems or job offer resulting in attrition was low for North American doctoral students, but ranked higher in Africa, followed by Asia and Europe (Table 4).

There were differences in major career placement of students after graduation; while the pharmaceutical industry was the major career after graduation in North America and Asia, 63% and 59%, respectively, this was less so in Europe, Africa and Australia (Fig. 3B). In Europe, 24% of students accepted positions in the pharmaceutical

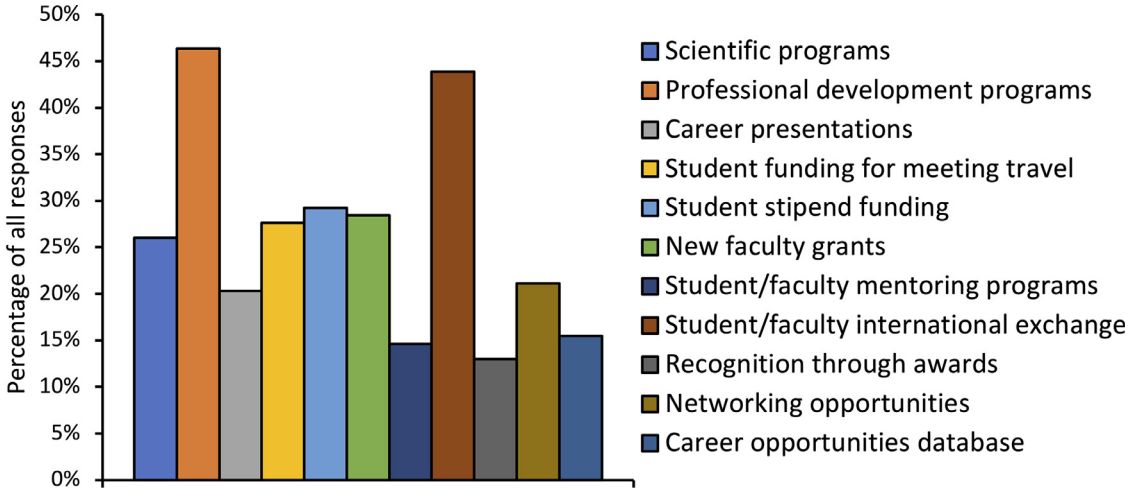

Figure 4. The role that professional scientific organizations should play in assisting with the scientific and professional development of faculty members and graduate students in doctoral programs in the pharmaceutical sciences.

industry, followed by 29% in community or hospital pharmacy. In Africa, 17% of students went into careers in the pharmaceutical industry. In comparing India and Japan, the major career placement in India was the pharmaceutical industry (75%), while this was 43% in Japan; more students went into academia and community/hospital pharmacy in Japan. In Australia, the major placements of graduates are postdoctoral fellowships and community/hospital pharmacy (Supplemental Table 2g).

Faculty Members Participating in Graduate Education

The number of faculty involved in graduate programs as advisors varied similarly across the geographical regions. When comparing female faculty members, European programs indicated 57% of programs had >50% females, while Asia reported 22% and North America 28% with >50% female faculty. African programs have predominantly 25-50% female faculty and Japanese programs have predominantly 10-25% female faculty (Table 5 and Supplemental Table 2e).

Major Challenge/Threat Faced by Ph.D. Graduate Programs

The major challenge faced by the graduate program was decreasing faculty member funding in North America and Africa (Table 6). In Europe the major threat was decreased graduate student funding, and this was a close second in North America. Australian programs indicated that decreased faculty and student funding were the major challenges. The major challenge in Asia was decreasing interest in graduate programs in the pharmaceutical sciences, although this was predominantly due to the responses from Japan. The responses from India indicated that decreasing career opportunities was the major challenge.

How FIP can Assist Graduate Programs

While professional development programs, student stipend funding and student/faculty exchange were overall ranked the highest of the list of opportunities, there were geographical differences. Africa also ranked scientific programming, new faculty grants and networking opportunities highly, while North America also ranked student funding for meetings, new faculty grants and student/faculty mentoring programs highly. Australian programs ranked faculty funding and student stipend support highest, but this was followed by student travel support and networking opportunities (Fig. 4).

Discussion

Our global survey of graduate programs in the pharmaceutical sciences offered in Schools of Pharmacy indicated that doctoral programs ranged from small (<10 Ph.D. students and/or <10 faculty mentor) to large (>100 graduate students and/or >50 faculty mentors). External review of programs occurs for 75% of programs, either every 2-4 years or 5-7 years; this represents an important quality control for both small and large programs, and one that has been emphasized since a review by Triggle in 1999.[10] A more recent international survey that included 4 biomedical programs: Vanderbilt University, University of Manitoba, Karolinska Institutet and Graz Medical University, emphasized the importance of quality assurance in doctoral education.[1]

The pharmaceutical sciences doctoral programs varied in requirements for admission to the program. Most programs were full-time with a length of 3-5 years in duration, with typically longer durations in North America, likely reflecting the greater amount of course work required in North American Ph.D. programs. A review of a select number of US programs in the pharmaceutical sciences at public research universities, indicated a range of times to graduation ranging from 4.3 to 5.7 years (Morris, unpublished). The majority of Ph.D. students in North America enter programs following completion of a bachelor's degree, with research experience gained through the B.S. degree, or in some cases through additional working experience or a master's degree. Generally, after 1-2 years, after completing the core curriculum, students take a qualifying (preliminary or comprehensive) exam, that can be written and/or oral. After introduction of the Bologna Process in Europe, undergraduate education was split into B.S. and M.S programs with the master's courses forming the basis for admission into Ph.D. programs.[13] However, in a large number of European countries, a combined 5- to 6- year BS/MS system remains, prior to Ph.D. admission.[1] Coursework is concentrated during the master's program, resulting in less course requirements during the Ph.D. program, no qualifying examination and shorter duration of programs, as reported in this survey.

Program requirements regarding internships, teaching assistantships/supervised teaching and core curriculum were similar across geographical regions. Publications have addressed core educational learning outcomes (core competencies) for graduate education in the pharmaceutical sciences. Core domains were described by Poloyac et al in 2017[8] as the following: 1. Foundational knowledge; 2. Research; 3. Scientific communication; 4. Education (teaching and learning); 5. Leadership and management; 6. Personal and professional development. Each domain contains educational learning outcomes that were included in this survey (Table 3). These learning outcomes include what have been called "Survival Skills", which include oral and written communication skills and research ethics, among others.[11] In Europe, the Organization for Ph.D. Education in Biomedical and Health Sciences in the European System (ORPHEUS) defined a similar slate of educational learning outcomes. Overall, these learning outcomes were included in the reported graduate curricula, with the lowest emphasis on grantsmanship (33%), followed by intellectual property (44%). As well, presentations on careers were present in 66% of programs. Little data exists on what skills employers expect of new Ph.D. graduates entering the workforce, but this was addressed in a survey of 12 pharmaceutical scientists with diverse career pathways.[7] The themes identified for skills that employers seek in doctoral graduates include: (1) Knowledge; depth and breadth of scientific knowledge, research and methodological skills; (2) Communication: verbal and written, communication within an interdisciplinary setting; (3) Collaboration; (4) Motivation and Curiosity; (5) Adaptability; (6) Experiential Training; (7) Critical Thinking and Problem Solving. These themes identified as skills desired in new Ph.D. graduates emphasizes the importance of the core curriculum in graduate programs, as well as the role of mentor advisement and support for preparing Ph.D. graduates for careers in the pharmaceutical sciences.

Requirements for graduation included 70% of programs requiring peer-reviewed publication and 80% of programs requiring a thesis defense with external and/or internal reviewers. ORPHEUS recommended that the thesis should contain the equivalent of 3 papers with fewer papers sufficing if published in high impact journals; however, the organization allowed the local assessment committee to decide regarding number of publications.[1] A requirement for peer-reviewed publications as a requirement for graduation is less common in North America and Australia, although student peer-reviewed publications remain an important component of graduate education globally, and are actively encouraged.

One area of interest is the percentage of female students in programs and female faculty as mentors. Lebovitz et al.[5], reported that 47-to 50% (average of 48.4%) of Ph.D. graduate students in the United States were female in 2017 and that this had not changed over the last 10 years. Additionally, 44.9% of Ph.D. degrees conferred in Schools of Pharmacy in the United States were to women. Our data supports that a high percentage of Ph.D. candidates are female, and

this percentage may be somewhat higher in Europe. Female faculty advisors represented <50% in 72% of Ph.D. programs, so may lag behind the number of females in Ph.D. programs, particularly in Asia and Africa. Female faculty in US pharmacy schools have been reported in a number of publications including by Draugalis et al. and Lebovitz et al.[3,4] In pharmacy schools in the United States, female science faculty increased by 46% (from 535 to 783 in number) from 2008 to 2017.[4] However, the total number of male science faculty remained higher than females with an overall ratio of 2.2:1.[4]

Lebovitz et al.[4] reported that following completion of Ph.D. degrees or postdoctoral fellowships in Schools of Pharmacy, 43% of graduates entered a career in the pharmaceutical industry and 42% went into academic careers. Mclaughlin et al.[7] reported that there is about one tenure-track position in the biomedical sciences for every 6.3 Ph.D. graduates, indicating the need for alternative career pathways. While our population only consisted of graduate students obtaining their Ph. D. degrees, our survey found 53% of graduate students entered a career in the pharmaceutical industry, 11% went into postdoctoral fellowships and 18% obtained a position in academia. Even if all 11% that entered postdoctoral fellowships subsequently accepted positions in academia following their postdoctoral positions, the total is less than the 42% reported by Lebovitz et al. that went into academic careers. This may be due in part to the 12% in this global survey that go into pharmacy careers. The percentage of doctoral graduates following careers in the pharmaceutical industry was 59% for Asia, 63% for North America, 33% for Africa and 24% for Europe; values were also low for Australia. In Asia, there was a high percentage of graduates in India entering positions in the pharmaceutical industry, but this was lower in Japan. These results likely reflect the extent of pharmaceutical industry in different countries. Percentage of students entering postdoctoral fellowships was low for Asia (6%) but similar for Europe and North America, 18% and 19%, respectively.

A number of challenges were identified by programs when asked to identify their program's major challenge. The highly ranked challenges were faculty funding, graduate student funding and decreased interest by students in Ph.D. graduate programs. Faculty funding and student support have been identified as major challenges in US programs.[4] Surveys from Asia and Africa also highlighted decreased career opportunities. Further outreach to FIP Board of Pharmaceutical Sciences members confirmed these choices. When asked to identify programs that FIP, a professional organization for pharmacy and pharmaceutical sciences, could provide to support graduate education, the top two types of programs were professional development programs and student/faculty international exchange. Increased networking opportunities can also lead to student/faculty international exchange, as indicated by comments to this question. These results indicate a need to increase professional development programs, as well as continuing to focus on supporting programs for graduate student/faculty exchange internationally. However, there are geographical differences, with scientific programs, new faculty grants and networking also ranked highly from African programs, and student funding for meeting travel ranked highly by North American programs. Therefore, outreach efforts need to address the specific challenges indicated by geographical regions and countries.

Limitations of the survey include the potential response bias, in that responses may have been obtained from predominantly very good or excellent programs. Additionally, the results are also limited by country/area response rates, and therefore these must be considered in making comparisons by geographical areas. As well, geographical region comparisons may include limited responses from a large number of countries, or could predominantly be from 1-2 countries. The response rate to the survey is not known due to the multiple mechanisms used to reach international programs; nor is the number of pharmaceutical sciences doctoral programs in Schools/College of Pharmacy known.

Conclusions

Graduate programs in pharmacy schools include many interdisciplinary programs and new programs including Clinical and Translational Science, Bioinformatics, and Pharmaceutical Engineering. This survey on Ph.D. graduate programs in the pharmaceutical sciences represents the first survey to compile information globally on doctoral programs in the pharmaceutical sciences. The survey included a range of graduate programs in Schools and Colleges of Pharmacy, with varying titles, but generally fitting under the umbrella of pharmaceutical sciences. As an initial survey to examine graduate programs globally, in depth information on students, faculty and research areas was not obtained; these areas require follow-up surveys.

This survey was our first attempt at mapping the global pharmaceutical sciences workforce, to assess the program strengths and challenges and devise a strategy for the international professional organization FIP and other professional organizations to meet the educational and research needs and challenges of doctoral programs. Additional studies are needed to further evaluate global workforce, both graduate students and pharmaceutical science faculty, and educational and research missions in doctoral pharmaceutical sciences programs.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.xphs.2022.07.001.

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