What We Know about the Dramatic Increase in PhD Degrees and the Reform of Doctoral Education Worldwide: Implications for South Africa

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Theories of the "knowledge economy" view knowledge, and particularly new knowledge, as a critical resource to enhance a nation's economic growth. Governments around the world have invested in doctoral education expansion. Reforms in doctoral education are being shaped by the changing needs of society, of research modes, and of a changed labor markets for PhD holders. The reform elements strive for excellence, expansion, quality assurance, accountability, and international and inter-sector network building. The expansion in doctoral studies has gone hand in hand with an increased flow of international doctoral students, the wish to become a world-class university, and the adoption of more standardized structures and practices of doctoral education. This paper ends with a number of promising reform practices that may be useful for South Africa's expanding doctoral systems, such as the introduction of postgraduate schools that help implement and initiate innovations in doctoral education on a campus with an eye to high quality.

Keywords: Doctoral education worldwide, globalization in higher education, reform in doctoral education, increase in PhD production, promising practices.

With a population of just 330,000 and total area of 103,000 square km., Iceland is a very small country. Yet, despite its recent financial crisis, it is a highly developed economy and one of the most advanced nations in the world. Not long ago, the annual number of "home grown" PhDs was 10, but in only 13 years enrolment jumped to 335, largely with the support of governmental grants, fellowships or special loans (Gudmundson, 2008). Furthermore, Icelandic scholars have been enticed back from foreign institutions to form a small but highly respected research community actively contributing to Iceland's entrepreneurial development. Focusing on the country's vast natural resources – geophysics and geothermal energy forces, fishing and fish-processing technology – this increased research capacity and the newly developed industrial research environments, in turn, have expanded and enriched higher education, including PhD production. Iceland has accomplished much of these developments by setting up cooperative agreements with universities around the world for student research exchanges and joint programmes and degrees.

In several ways, the story of the doctorate in Iceland is a global story. Since the 1990s, nations around the world have been increasing doctoral degree production and introducing initiatives to reform their master's and doctoral programmes. These include nations as small as Iceland or as large as China, nations with long traditions of doctoral education such as Germany, or with shorter traditions such as Australia, Brazil or Malaysia. The recent consensus report of the Academy of Science of South Africa concludes that the country's future development depends on the production of more high-quality PhDs (ASSAf, 2010). Clearly, South Africa is not alone in taking a fresh look at its doctoral education.

Why are such initiatives occurring at the same time around the world? Why are both resource-rich countries with highly developed higher education systems and countries with emerging economies and young, advanced higher education systems reforming postgraduate education? The answers reflect the effects of globalisation on higher education, in general, and doctoral education, in particular. They also reflect significant demographic shifts in some countries, and an overall rapid increase in internationalisation activities at the postgraduate level.[1] This article seeks to explain these developments and place the South African national concern about low production of high-quality PhDs in an international context. It concludes with recommendations based on successful reform efforts in doctoral education around the world.

The knowledge economy and doctoral education

Natural resources are no longer the key factors in economic growth and sustaining international competitiveness. Instead, in today's global economy, knowledge is viewed as a critical resource for nations. National governments and even supranational entities such as the European Union and World Bank have promoted science, technology and innovation policies to enhance economic growth (Marginson, 2009; Yusuf & Nabeshima, 2007). These include attracting international business investment by developing world-class academic research facilities, which are seen as resources for discovery, innovation and highly skilled workers (Altbach, 2007; Salmi, 2009). New knowledge, it is hoped, will ensure prosperity for the general citizenry by generating technological innovation, new products, new firms or expansion of existing ones, and by creating high-paying jobs (Dill & Van Vught, 2010; Slaughter & Leslie, 1997). This thinking is driven by knowledge economy theorists who attribute economic growth to the unexpected novel ideas that lead to scientific, technical, organizational, environmental and health innovations (Powell & Snellman, 2004; Slaughter & Rhoades, 2004). Universities are sites of innovative research and the number and quality of doctoral students are critical to university research because doctoral students are centrally involved in the academic research work – doctoral theses produce a significant amount of new knowledge and, more importantly, doctoral education produces future researchers. As the knowledge economy theory has been more widely accepted around the world, national governments in many places have turned to master's programmes and doctoral education as a way to prepare their future generations as innovators in all areas of society, but particularly in science and technology.

Eagerly seeking to stimulate economic growth, national capacity building and international cooperation as well as competition, governments are allocating substantial funds to increase the research and development capacities of their countries. Postgraduate education is included in these funding allocations. The education of outstanding scholars and professionals who are able to bring innovative changes to their workplaces – in business, government, academia or non-profit sectors – is increasingly considered to be part of research and development activities and included in national innovation policies. No less important is the fact that countries internationally recognised for world-class, successful research capacities are those that attract major investment money and create new jobs and markets.

The new mode 2 doctorate

It is not just a matter of how many master's and doctoral degrees are awarded each year. Each degree has to represent the best possible education that will contribute to solving societal problems and push forward the frontiers of knowledge. This means that, as countries and their institutions expand capacity, they must simultaneously be re-thinking how they educate their next generation of professionals and researchers. First-class research minds are not shaped by rote learning during the early years of schooling, nor limited to narrow, singular disciplinary research approaches without exposure to views from other disciplines. Instead, education and research training have to be organised with a problem-solving approach, using multi-disciplinary teams and including participants from various sectors of society. Finding answers to the many societal problems has become too complex and too costly to be solved by one researcher, one singular disciplinary approach or one university.

It is widely believed that PhD education must incorporate new elements in order to produce the kind of scholars, researchers and leaders needed for the future (National Academy of Siences 2007). Reforms aimed in this direction include efforts to prepare graduates to undertake "Mode 2" research and equip them to work effectively in a variety of employment sectors and types of careers within the emerging, global knowledge economy and information society (Bartelse & Huisman 2008; Nerad 2009; NSF 2000). Mode 2 designates research characterised by solving problems which have been defined by society, by including participants from various sectors of society, and by tackling big challenges requiring multi-disciplinary approaches (Gibbons *et al.*, 1994). In contrast, in so-called Mode 1 research, investigators solve isolated disciplinary puzzles; and students learn from one master scholar within one discipline (Gibbons *et al.*, 1994). This describes the traditional model of PhD education. Today's reforms seek to preserve disciplinary excellence while preparing students for multi-disciplinary, team-based research. They tackle real-world

problems and learn to work effectively in international contexts and at the interfaces of academy/industry and academy/society, as well as in academia, industry, government and non-profit sectors (Adams *et al.*, 2005; Stokes 1997).

Expansion of doctoral education

In recent decades, PhD production worldwide increased greatly. In science and engineering alone about 174,000 doctoral degrees are awarded in the world annually. In 2006, 52,000 degrees were awarded in the European Union. With about 30,000 science and engineering PhD degrees conferred in 2006, the United States still produced more PhDs than any other country, accounting for about 18% of world output.[2] But growth in other parts of the world has far outpaced US growth in PhD production. Between 1985 and 2005, for instance, the number of science and engineering PhDs awarded in Germany, Japan and the UK nearly doubled. China's output soared from fewer than 1,000 in 1985 to more than 14,000 in 2004. In Japan, bachelor's and master's level education traditionally supplied industrial researchers, who were then trained within the industry. The PhD was conferred mainly as an honour after a long career. Today, in Japan, the number of science and engineering PhDs awarded is increasing, more than doubling from 3,088 in 1985 to 7,658 in 2005.

As PhD output increases, the demographics of doctoral students are changing. The proportion of female PhD recipients is rising and there is an increase in the average age of doctoral students (Evans and Marsh 2008*;* NSF 2006, appendix table 2-41; NSF 2008, appendix table 2-41). With these figures, a clear picture emerges of global trends in doctoral education. In the US the proportion of women who were awarded PhDs in 2009 has come close to par (46.8%) with men (NORC 2010). More 30-year-olds and older begin their doctoral study after a period of employment. This is coupled with a growth in part-time PhD students. Also notable is the proliferation of professional doctorates such as in nursing and physical therapy.

The relatively modest growth in PhD production in European countries, as indicated above, is largely driven by an increase in international students. Specifically in English-speaking nations and in countries where doctoral education is now offered in English, the numbers of international doctoral students have increased substantially.

Attracting international doctoral students

Not all nations have the capacity to produce more PhDs from among their own populations. Some are "graying" nations with low birth rates (e.g., Japan, northern Europe, Germany); others annually graduate only a small number of high school students eligible to attend college and proceed to the PhD. Countries with low birth rates or small populations try to attract highly skilled workers through the back door of education. To attract excellent international postgraduate students to their universities, these countries allow international doctorate awardees to remain in their countries and contribute to economic growth through innovations, research, and development. Historically, a "brain drain" in doctoral education was assessed as a loss to the home country. During the last decades such countries have come to realise that these expatriates invest in their country's economy and often return when the home country provides interesting opportunities. India and South Korea are good examples.

In light of low birth rates, the UK, Japan and Germany have launched massive recruitment efforts, particularly for their science, engineering, mathematics and agricultural doctoral programmes. In the UK an international student market analysis agency assesses foreign countries and the likelihood that their students can be recruited to UK universities. Private firms advertise and recruit overseas for UK universities. Japan has an initiative called "100,000 students from overseas" to attract more international students to its universities (Yamamoto, 2008). Australian and New Zealand universities and, more recently, Canadian universities, are recruiting heavily abroad, most notably from Asian or Caribbean countries (Evans T 2000; Pearson 1999). Starting 2005, even the US, a country that continues to attract the largest number of international doctoral students without recruitment, began participating in an international recruitment fair in China. The initiatives to attract international postgraduate students, who may remain in the host country and contribute to the local economy, must be linked to a nation's favourable immigration policies.

It is difficult to provide robust comparative numbers on the flow of international doctoral students, as countries have different systems for allowing international students to become residents. For countries where we know the percentage of doctoral degrees awarded to international students between 2003 and 2005, we see marked increases. In Germany, for example, the proportion of international students among all PhDs awarded increased from 10% to 16% (3,556 international doctoral recipients) (NSF 2006, 2008, appendix table 2-49). In the UK during the same three-year period, of all the PhDs awarded, the proportion of international students increased from 39% to 42% (6,650 international doctoral recipients), while in the US the percentage increased from 30% to 33% for a total of 14,424 doctorates (NSF 2006, 2008).

Re-thinking and reforming doctoral education

Besides increases in the production of doctoral degrees, many countries have instituted reform efforts to improve the quality and efficiency of doctoral education. Individual country initiatives show common elements of striving for excellence, expansion, quality assurance and accountability, and international and inter-sector network building. Outside of North America, PhDs have traditionally been earned in a dyadic master-apprenticeship relationship rather than within a structured programme with a cohort of students. Today's trend is toward structured doctoral programmes, including multiple supervisors (i.e., committees rather than a single advisor and often with international members) and coursework requirements (Nerad & Trzyna 2008; Teichler & Yagci 2009). Where they do not already exist, graduate schools ("research schools" in Europe) are being established, which develop university-wide guidelines for doctoral education, codes of practice for the supervision of PhD students, faculty development offerings, assessment of PhD education, and incentives for mentoring. Given South Africa's need to increase its PhD production in science and engineering (ASSAf 2010) the following models of PhD production, which are linked with the industry, will be of interest.

New models of knowledge production: Linking university with industry

By creating programmes that link universities more closely to industry and the public sector, countries such as Australia and Brazil, and European Union countries (EC 2010) hope that doctoral graduates learn to transfer knowledge acquired during their studies to places that will immediately use and apply this knowledge. The links between government, industry and university in this new mode of knowledge production are often referred to as a "triple-helix" (Etzkowitz & Leydesdorff 2000; Harman 2008). The latest European Commission paper on Europe 2020, *Flagship Initiative: Innovation Union*, speaks of the necessity in times of fiscal constraints to invest even more in higher education for job creation and innovations, and systematically link researchers, creativity and ideas to goods and social services (EC 2010).

The Australian Cooperative Research Centers (CRC), established by the Australian government in 1990, is an example of these links and new modes of knowledge production. The goal of the CRC is to produce "end-user driven" or "employment-ready" graduates (Harman 2004; Harman 2008; Manathunga *et al*. 2009) not only for the industry, but also for the public sector. These centres emphasise collaborative, multi-disciplinary and commercially oriented research.

In 1990 Germany introduced structured, interdisciplinary, theme-oriented doctoral programmes, the *Graduiertenkolleges*, involving professors from several universities, and often having an international orientation (Kehm 2008; Nerad 2004). Hundreds of *Graduiertenkolleges* are each funded for up to nine years.

In 1997 the US introduced similar programmes to train doctoral students by working within multi-disciplinary teams on topic-driven research, in addition to acquiring traditional disciplinary research training (Nerad, 2008). In 2005 the US introduced international research and training programmes, the "Partnership in International Research and Education" (NSF/PIRE).

World-class universities

In order to indicate preparedness for innovations in the employment sectors and new markets, governments strive for world-class research preparation and research production. Ireland, Japan, Germany, Malaysia,

and recently Canada have, or are talking about, creating such world-class universities. Japan began funding centres of excellence in 2002, under the 21st Century Center of Excellence (COE) Program to strengthen and enhance the education and research functions of graduate schools (JSP n.d.).

In 2005 Germany created an *Exzellenzinitative* (Excellence Initiative), which aims to make Germany a more attractive research location and more internationally competitive. Between 2006 and 2011 the German government has been providing €1.9 billion in additional funding to create more graduate schools for the promotion of young scientists. This funding also supports development of institutional strategies and implementation of clusters of excellence to promote top-level research. In 2005 Germany extended the push to creating world-class universities via the excellence initiative. Under this programme universities are encouraged to apply for interdisciplinary graduate schools, Excellence Research Clusters, and innovative university profile developments which include elements such as close links to industry. For these competitive grants €2.7 billion will be allocated until 2017 (DFG 2009).

Similarly, in 2007 Malaysia adopted an *Excellenzinitiative* in the form of so-called apex universities in order to create excellent, world-class universities (Sirit 2009). China has similar initiatives (Hayhoe & Pan 2005; Yamamoto 2008).

Examples of changes in postgraduate education worldwide

The following are examples of how individual countries have made postgraduate education a part of national innovation policies.

Europe. In the Bologna Declaration, Europe announced its goal of becoming the leading knowledge-based economy in the world by 2010. European Union leaders vowed to allocate 3% of the GNP to research and development in their countries by 2010 (Nerad & Trzyna, 2008). Plans to implement this goal included doctoral education and the necessity to increase the number of doctoral candidates.

Ireland. In 2005 Ireland, a member of the European Union, developed a comprehensive plan to become a leading knowledge economy by 2013. The government's strategy for science, technology and innovation included a tripling of their research and development investment in the higher education and business sector. This strategy included (Irish University Association 2007):

- Building a world-class research system by increasing the numbers of researchers trained in Ireland and by attracting highly skilled, research-active individuals to Ireland. This was coupled with changing doctoral education to structured programmes.
- Capturing, protecting and commercialising ideas and know-how.
- Driving growth through research and innovation by taking research outputs with commercial potential and bringing them to a point where they could be transferred to industry.
- Providing a solid foundation in primary and secondary education through improved teachers' education, creating professional development and networks for teachers and emphasising effective methods of science teaching.
- Ensuring that all parts of the research and education system worked well together

While the country has recently experienced a severe economic crisis, its postgraduate reform goals have not changed significantly.

By focusing on growth in research capacity and by increasing the reputation of its universities, coupled with an enhanced research and development tax credit arrangement, Ireland set up significant industrial and academic research collaborations. In the expansion of advanced degrees, Ireland focused on areas in health, agriculture, marine, energy and environment sectors.

Brazil. The National Plan for Postgraduate Studies 2005-2010 is a part of the Brazilian government's plan for self-sufficiency in the principal sectors of society. The specific strategies of the postgraduate studies plan included (Riberio 2008):

- Increasing the production of advanced degrees, master's and doctoral degrees, doubling the number of faculties with doctoral degrees within a 10-year period, and increasing doctorates awarded in areas of relevant economic development.
- Changing the national fellowship system, aligning doctoral education with the national goals of self-sufficiency in principal sectors of the economy.
- Creating links between the academic world and the world of production.
- Investing in research and development in the academic sector as well as in industry and business with an investment of $660 million for these goals.
- Implementing a clear, transparent national quality evaluation system coordinated by a Council for the Improvement of Higher Education Personnel and the National Research Council.

India. In 2005 the Indian National Knowledge Commission, an advisory body to India's Prime Minister, stated that the country needed a knowledge-oriented paradigm of development to give it a competitive advantage in all fields (Jayaram 2008). In 2007 the Department of Science and Technology, among others, allocated funding to increase PhDs in nano-science. India's expansion of doctoral production is not only a response to intra-national needs, but also a response to the establishment of research and development centres of multinational-national companies and emerging collaborations between these research and development centres, Indian universities, and research institutes and Indian companies (Jayaram *et al.* n.d.). These developments are concentrated in biotechnology, computer software development and nano-technology.

Malaysia. Malaysia is positioning itself as the higher education hub in the Asian Pacific region. It has recognised that the cost of education in countries such as the UK, the US and Australia has increased and that, given Malaysia's geographic location and religious diversity, it is in a good position to welcome international students. Its 2007 National Higher Education Strategic Plan focused on:

- Increasing the proportion of academic staff who hold doctoral degrees from 30% to 75%.
- Implementing quality assurance indicators, which include quality of academic staff, the quality of the infrastructure, and the quality of the learning and teaching content.
- Establishing centres of excellence at a small number of universities through competitive applications to become apex universities. To become an apex university, it has to demonstrate a willingness to search for innovative ideas, a preparedness for change, and a readiness to implement the changes by means of a detailed plan.

In its expansion of postgraduate education, Malaysia's apex university, Penang, is focusing on research that seeks poverty reduction, providing wide access to health care, education and food for everyone, and spreading environmental awareness (Sirit, 2009), Institute of Postgraduate Studies 2009, Malaysian Ministry of Higher Education 2007).

A global mode of PhD production

In spite of the differences in doctoral education systems and innovation practices, a review of university statements from countries in the East and the West identified three common features pertaining to the **research** doctorate: (a) a research doctorate should contribute to knowledge through original research; (b) the doctoral graduates are expected to have a substantial knowledge in their area of study; and (c) there is an increasing agreement that doctoral training should include development of transferable professional competencies and that these competencies are an integral part of becoming a researcher in one's field (Bernstein *et al.* n.d).

Beyond this common understanding of what a doctoral degree entails, the following converging practices have emerged around the world:2

1. Selection and admissions

- More and more countries allow access to doctoral programmes after a bachelor's degree as opposed to only after first earning a master's degree.
- The admission procedure has become a competitive, defined and formalised process.
- To attract outstanding applicants, students are now offered several years of funding. In some countries funding comes directly from the government. In other countries such as the US they are funded indirectly by the government through research grants, or by the states through teaching assistantships. Students increasingly are offered a three- to four-year funding package.

2. Programme elements

- To be attractive to international students many countries offer their doctoral education training in English. English has become the *lingua franca* of doctoral education, and many academic journals are published in English.
- Students work with more than one supervisor or advisor. A dissertation committee, a panel of several people, guides the doctoral students throughout the dissertation process.
- Increasingly, students, especially in the sciences and economics, have the option of choosing between a traditional dissertation and a compilation of several peer-reviewed articles based on their research. Universities are beginning to adopt policies that recognise such articles and also thesis chapters with multiple authors.
- Countries that traditionally have not administered examinations during doctoral study are introducing oral examinations.

3. Doctoral education as academic and professional preparation, with a global view

- Students are prepared for a variety of careers, not just becoming a professor, but also for doing research and teaching in industry, business, governments and non-profit organisations. Doctorates are increasingly seen in non-academic careers.
- Training in professional skills is offered through the graduate school or research school. This training focuses on conducting ethical research, working effectively in teams, knowing how to teach, how to publish, how to present, how to communicate complex information, how to write group grants, how to manage time and projects.
- Universities make efforts to provide international experiences for their postgraduate students.

4. University and national policies, structures to guide growth and development of PhD programmes

- Where not already in existence, graduate schools are established to develop overall guidelines for the doctoral education process. These graduate schools are, in conjunction with academic departments, developing codes of practice for supervising faculty members. They increasingly offer training for supervisors and develop evaluation surveys assessing what students think about their programmes and the faculty's advice. Departments and graduate schools offer incentives for good mentoring through special awards.
- National funding agencies and universities are creating templates for the review of doctoral programmes which synthesise international standards on PhD programmes. They are reaching out to international review teams for programme review.
- Funding and regulatory agencies are asking doctoral programmes to undertake formative and summative evaluations for ongoing programme improvements.

Recommendations based on international experiences

Clearly, doctoral education around the world has entered a new era, marked by many significant, exciting developments. For South Africa, or any country seeking to drastically expand doctoral education, and whose doctoral education is based on the British model, six practices are suggested based on successful experiences. Following is a description of these six practices, combined with names of countries where they were successfully applied.

1. Development of a strategic increase in postgraduate education must be aligned with South Africa's national innovation and development scheme and has to address multiple societal needs:

   (a) Develop a 10-year plan for doubling the number of academic staff with doctoral degrees in all fields (Brazil, Ireland).

   (b) Target a portion of the increase in fields that influence economic growth (Ireland, Brazil, EU, Malaysia).

   (c) Create novel world-class doctoral programmes (Brazil, Ireland, Iceland, Malaysia).

   (d) Create more professional master's programmes.

   (e) Plan for a regionally balanced increase (Brazil).

2. Embrace "brain circulation". The "brain-drain" has historically been experienced by many resource-poor nations with few world-class universities, but now these countries are turning past losses of excellent minds ("brains") into a positive situation. They entice back expatriates who have become outstanding researchers. South Korea, Australia, Ireland, Germany, China and, most recently, India have all set up systems to bring back to their universities (permanently or for a few years at a time) eminent scholars in areas of national and institutional needs. These countries allocate a considerable amount of funding to make such a move attractive. In these schemes, Germany, for example, provides funds to support employment of spouses in cases of dual-career scholar couples (e.g., the German Alexander von Humboldt distinguished professorship). In the case of South Africa, offers which aim to return outstanding scholars and which involve exciting missions to help expand and produce high-quality research and to train graduate students in the process, could be attractive to committed minds. Success is likely if several universities and industrial research centres work together on such opportunities.

3. A differentiated higher education system can more readily provide education that addresses local needs.

   (a) Not all universities need to offer all doctoral degrees. Centres for excellence need to be built according to existing expertise at different universities. Furthermore, research specialisation must be combined with a sufficient critical mass to make quantity and quality of PhD production more feasible.

   (b) Not all higher education institutions need to grant PhDs (see Brazil, or the California Master Plan for Higher Education, which differentiates by functions and degrees among its three types of higher education institutions and has a strong system of articulation among the different institutions).

4. South Africa can create a prestigious national fellowship which includes a maximum of two years of study at a foreign university to ensure international exposure. Such fellowships ensure education with the international exposure necessary for a global employment market. Brazil, China, Thailand and Demark all have successful programmes to support students to study abroad. These fellowship recipients come with their own money and are welcomed by host universities as no extra expenses are incurred.

5. South Africa can more readily disseminate the latest knowledge when concerted and coordinated efforts are made to bring together representatives of universities, research councils, governments, non-profit organisations and industries in on-going round-table meetings. If these meetings with representatives from outside the university include planning activities with regard to broadening information about the career possibilities of aspiring doctorates and possible mentoring of current master's and doctoral students by men and women in industry, business, government or non-profit organisations, the gap between inside and outside academia could begin to be bridged. Australia, Ireland and the US are good examples of round-table activities, with representatives from relevant sectors of society meeting regularly to discuss labour force needs and plan activities which provide universities and their graduates with up-to-date information on these needs and skills. Germany, for example, has implemented industrial mentorship programmes for female science and engineering doctoral students to meet regularly with female mentors from the industry as a measure to increase the number of successful female engineers and scientists working in the industry.
6. In South Africa's drive to increase PhD production, the introduction of a single graduate school to support academic staff and students and to ensure quality and equality across fields can be a major asset. Recent European implementation of various forms of graduate schools has found the American model of a single graduate school to be superior to several decentralised research schools.

The graduate school is closely linked to the research agenda of the university. A graduate dean heading the graduate school belongs to the inner circle of a university's governance. The graduate school is both an administrative and an academic unit. It has five basic functions:

- It is the executive policy body of an academic senate committee which ensures the quality of master's and doctoral education across the entire university.
- It is an administrative unit for all matters of postgraduate and postdoctoral affairs. As such, it oversees the basic requirements of admissions and degrees.
- It is a service unit for postgraduate programmes and postgraduate students. In this function, it provides additional professional skills training which allows doctoral students to be successful in a variety of employment settings.
- It is an institutional research unit for postgraduate matters and it collects and analyses data on postgraduate education at its university. Institutional research serves as a basis for policy setting.
- It is an initiator and catalyst for innovation in postgraduate and postdoctoral matters.

In sum, if strategic increases in postgraduate education are linked to the South African national innovation agenda, changes will have great potential for success. If these quantitative changes are paired with changes in the way doctoral education training is structured, and doctoral students are treated as junior colleagues in a community of research practice, then these changes will result in a high-quality education. The efficient and effective use of existing resources and the collaboration among South African universities and with government, business and industry with regard to the use of expensive research equipment will ensure that high-quality research training occurs faster and that the transfer of knowledge from the university to the industry advances more quickly. Following the successful examples of South Korea and India, South Africa can attract expatriate South African researchers and scholars who are committed to rebuilding the new South Africa. In doing so, plans for quantitative increases and qualitative changes in doctoral education may come to fruition more quickly. Establishing postgraduate schools in the South African universities may be the way forward.

As South Africa refines its national innovation agenda, it should not underestimate the role that postgraduate education can play in helping the country to meet its long-term economic and social goals. Bold, smart and highly educated men and women, applying their innovative talents and knowledge across academia, government, business and industry will become a most valuable resource for the country. This

next generation will support the "knowledge economy" critical to South Africa's internal growth which, in turn, is linked to an international presence.

How is this great bank of knowledge and innovation to be built? Goals for postgraduate education must be both quantitative and qualitative. "Qualitative" implies thinking strategically and flexibly about how doctoral education is to be structured. As this article has tried to make clear, the traditional model is no longer adequate. Doctoral students today need to be treated as junior colleagues in a community of research practice and have access to the best resources and facilities. If South African universities collaborate with one another and with government, business and industry, existing resources can be used more efficiently and effectively. In addition, if South African universities collaborate with universities and research facilities around the world and provide opportunities for their students to spend time with other research groups, postgraduate research training and the transfer of knowledge will be cutting edge.

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(Endnotes)

1. An earlier version has appeared in the Higher Education Forum (Japan) Volume 7, March 2010 and is based on a talk presented at a symposium in South Africa in connection with the ASSAf Consensus Report of October 5, 2009.

2. Data in this paragraph drawn from National Science Foundation, Science and Engineering Indicators 2010 http://www nsf.gov/statistics/seind10/c2/c2s5.htm#s4.