Re-inventing inventiveness in science

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Much scientific research is mundane, often involving only incremental advancements to our understandings. Sometimes progress is marginal, for example when established methods are applied to different systems or when ideas and techniques are improved slightly. In this way, advances often come at a painstakingly slow rate, and not always in a linear fashion. Scientific dead ends are a part of the journey to scientific advancement.

Some will argue that it seems a luxury for scientists to be rewarded for unfettered research when their individual contributions to the overall advancement of the field of inquiry can be described as miniscule, with little or no direct impact on society or on commerce and industry. Given the enormous expense involved in supporting research at universities and our national facilities, especially in a developing country like South Africa, it seems fair to ask: Why should society, more specifically taxpayers, support open-ended scientific research?

Free open-ended inquiry as a basis for scientific advancement

This question has been dealt with in different eras by different societies, and many industrialised nations have long seen the necessity for nurturing a community of scientific specialists. It is not necessarily the individual contributions that count, but the aggregated understandings that can lead to important scientific advances. If we are going to progress, South Africa needs to be part of this journey.

At times, however, bright new ideas, incisive innovative theories and explanations, radically different techniques and approaches, ingenious inventions, unpredicted observations, and unimagined discoveries emerge. This type of scientific breakthrough often cannot be planned in advance nor can it be predicted. Nor can it be directed from the top, or orchestrated by managers and bureaucrats, although the support of these groups is essential. Scientific breakthroughs thrive where intellectual enquiry is supported and free.

Scientific advancement as a basis for directed, applied industrial research

Unfettered science may seem to be divorced from South Africa's practical problems. Should we, therefore, move in the direction of more directed, applied industrial research – by which I mean research focused on solving a known set of problems with direct benefit for commerce, industry, or society more generally – to address societal challenges?

There is a strong argument that directed, applied industrial research focused on practical problem-solving needs strong support, especially in a country like ours with high levels of poverty and unemployment. However, this research should not be done at the expense of free, open-ended inquiry. For if it did, we would run short of truly fresh scientific ideas to apply to our societal problems. We would destroy the source of high-quality young graduates with the capability and versatility to move towards directed, applied industrial research and thus we would destroy the entire scientific enterprise.

Quality postgraduate student training as a vital cog for societal development

The South African government has stated its aim to graduate 6000 PhDs per year by 2025. Currently, we produce about half this number annually across all disciplines. Although currently unrealistic, the target might be regarded as aspirational, but it also emphasises postgraduate student development as an instrument for societal change. (Here, by postgraduate students I mean the cohort of PhD students.)

It is important that we focus on quality postgraduate student development, and that we re-double our efforts to enable graduates to lead successful careers while making meaningful contributions to society. Unless we plan properly, this will not happen. Because the vast majority will not find academic employment, as our universities and research facilities have their own fiscal constraints, the need to train postgraduates for success beyond academia is extremely urgent.

Training postgraduate students in an environment of open-ended inquiry is vital for their personal development. This is where critical thinking is nurtured, and students require intellectual versatility. They must learn skills transferable to different employment settings. Thus, the question arises about how we can be more creative in postgraduate student training so that graduates can impact more positively on society without damaging the very ethos needed to sustain science into the future.

Unless we grapple with this question, we may run the risk of losing societal support for science. Having thousands of unemployed or underemployed PhDs will come back to haunt South African academia if we do not address this question timeously. Increasingly, it will be seen to be a failure if our postgraduates are not sufficiently inventive and if they are largely incapable of creating employment opportunities, at the very least, for themselves.

The following are, in my view, some of the principal areas in which we might re-orientate postgraduate student training to avoid what appears to be a looming future crisis of massive underemployment of highly qualified postgraduates.

1. Enhance critical thinking and the ethical practice of science

With ready and free access to information on the Internet, are our universities, and hence our graduates, becoming less relevant? It is likely that this will happen if we do not adjust our research, teaching and learning programmes. Despite the deluge of information, students still need to be taught the broad understanding of their subject material and assisted in making inter- and multi-disciplinary connections. They need to engage critically with their subjects and be trained to become more discerning about 'information'.

The ethical practice of science for humanity must become a very strong focus of our training across all scientific disciplines if postgraduate students will be more relevant for society. Society needs more scientists with a more humane view of this world.

2. Strengthen scientific and technical skills development

In many experimental sciences, the focus is on using off-the-shelf commercial equipment. While this often leads to excellent scientific outcomes, there is often little attention to innovating with the instrumentation itself. Thus, many postgraduate students become operators of equipment rather than its designers, modifiers or even developers. This impacts negatively on skill sets, often with reduced options for employment outside academia.

This reality replicates itself in many different scientific endeavours. For instance, in the fields of computational sciences a generation ago, students and postdoctoral fellows would have developed their own codes incrementally over many years. Today, many production codes have been commercialised with exorbitant licence fees, although the community of open-source developers is growing. These codes are highly specialised and sophisticated and written by teams of experts. It is obviously impossible for a postgraduate student to write an entire production code that can compete with what has been professionally developed. But we need students to be computationally competent if they are going to seek work in commerce and industry.

The reality is that these large-scale production codes are being used as 'black boxes' by postgraduate students and researchers alike. Students do not always learn computational theory and algorithms in a fundamental way, and many can barely make substantial modifications to the codes. Worse still, in the cases of most licensed software, the source codes are not available for scrutiny. The consequence is that science is impeded in very real ways. The question we should ask is: Are we producing computational scientists or computational operators?

The irony is that advances in science and technology, especially in automation – while important for society-at-large – have helped dull the creativity and inventiveness of our postgraduate students, with bleak consequences for their futures, and possibly for science itself. We need to fix this.

There is new science to discover if the limits of instrumentation can be pushed to new levels. Supervisors need to take a more pedagogical approach to training postgraduate students in using experimental equipment. Postgraduate students from all branches of science need to be capable of mechanical machining and electronic design. They should learn to be able to dissect equipment and discover its inner workings, to modify it and even design and build new capabilities

All students, including those in the humanities, should be able to write computer code. How else will they be able to translate a new theoretical model that they might have developed as a part of their research into tangible results?

We must impart to our postgraduate students the types of experimental, technical and computational skills that will enable them to succeed outside academia.

3. Exploring the path from science to innovation

Researchers are often accused by managers, funders and society in general of not being sufficiently innovative. There is growing pressure for universities to engage more with discovery and innovation. However, I have already argued above that open-ended unfettered research must continue to be the bedrock of our university research systems. Are we going to continue to live in separate worlds, or can we look for ways in which we can bridge this growing divergence?

The current enterprise system at many universities works as follows. When a new idea is discovered, it is identified and then advances along the long and arduous path toward commercialisation. A new set of skills and understanding is critical for this to happen, often totally unknown to the typical scientific researcher. For example, major funding is almost always vital; prototyping is necessary; extensive market research is needed; clinical trials may be required; intellectual property rights require investigating; patenting is expensive; etc.

This chain pre-supposes that new, commercially viable ideas are actively pursued in the research laboratories. This, however, is often not the case as many academics focus on their academic pursuits and do not actively seek marketable ideas. And even if academics stumble across an exciting new and marketable idea, they do not often have the time to take it further.

However, the situation is very different for postgraduate students who are not faculty members. The requirement for research papers of international standing, and a thesis, remain important requirements, but students need to be exposed to a different way of thinking about research. Research can lead to new ideas and discovery, but innovation reflects the chain of processes to bring this research to the market or in service of society, which, as was noted above, requires other knowledge and skills to which postgraduate students are not generally exposed.

We should educate and train postgraduate students to take innovative ideas through to market, by including practical real-life examples taught by successful experts, from the outset, rather than as an option to be considered only at the end when a student fortuitously finds an exciting idea that they wish to pursue. This cannot be left to chance.

We need a new conversation: How can we more effectively expose our postgraduate students to the ideas of innovation at the start of their studies rather than accidentally at the end? Inspiration can change attitudes. Not all PhDs will become entrepreneurs, but after such exposure, they will always seek the value of their work in terms of application.

The future of the South African academy depends on training an increasing number of highly qualified postgraduates who can readily be employed outside academia, or who can create their own employment. Major public funding and effort will be devoted to increasing our postgraduate student production rate as intended. If this is not accompanied by increasing quality and employability, then we are heading for catastrophe.

By focusing on the employability of our postgraduate students, open-ended unfettered research – which I have argued is essential for the long-term viability of our scientific research systems – must be able to continue in an unhindered way. The re-orientation of postgraduate student training along the above lines will enhance the quality for open-ended research and increase the attractiveness of postgraduate studies. The top 5% of PhDs may still find excellent academic jobs, but I expect and hope that they will, through the process I have outlined, have developed a greater understanding and sympathy for the plights facing the remaining 95%.

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