Educating the Next Generation of Scientists: what should the objectives be, and how can we achieve them?

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Abstract

The world has changed, and the role and responsibilities of scientists have changed as a consequence. Not only is there an increasingly urgent need for scientifically informed multi-scale responses to the global problems we face, but there is also a need to address to the obstructive attitudes toward evidence accumulated and presented through scientific activities. What skills will allow future scientists to continue extending the frontiers of knowledge, to cooperate in response to the wicked problems we face, and negotiate the complexities of denialism? These questions go to the very heart of what it means, and is likely to mean in future, to be a scientist. This in turn goes to the heart of the educational process that will deliver graduates able to address these conundrums. The implications of these considerations will be explored from curriculum design, learning outcomes, and pedagogic perspectives. We start by considering the value of longitudinal curricula, problem based learning approaches and authentic assessment strategies. We demonstrate the utility of an enhanced graduate profile framework as a tool for planning educational interventions across the scales at which they occur – institution, programme, module, session and individual learner. Based on our experiences in formal teaching, informal student support, and research training at both undergraduate and post-graduate levels, we will reflect on the value of such an approach to science education in this brave new post-truth world.

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Desperate times for science

Increasingly, scientists, policy makers, and educators operate in a context that is characterised by organized campaigns which spread doubt and encourage the rejection of scientific consensus on critical issues. In addition to the skill sets that allow scientists to fulfil their professional roles, scientists must be able to engage effectively in the public realm, and respond to science denialism.

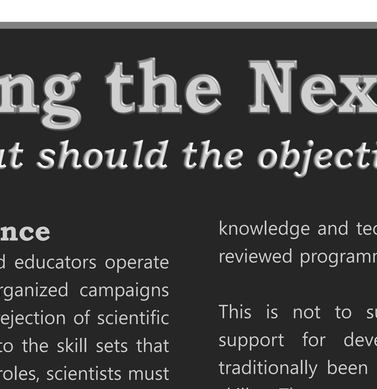
In this dystopic, post-truth world, evidence-based scientific knowledge is often sacrificed on the altars of political expediency, financial interests, and entrenched dogma - exemplified in this quote, from during the UK's Brexit campaign in 2016.

> *"I think the people in this country have had enough of experts from organisations with acronyms saying that they know what is best and getting it consistently wrong."*
>
> Michael Gove, UK Secretary of State for Justice, 2016

Such challenges and denial of science not only refute the findings of scientific research - "it misleads the public about how science works" (Rosenau 2012, p. 567). We should all feel obligated to defend the knowledge developed through our collective endeavours, as well as the principles on which they are founded.

Tradition has served us well, but...

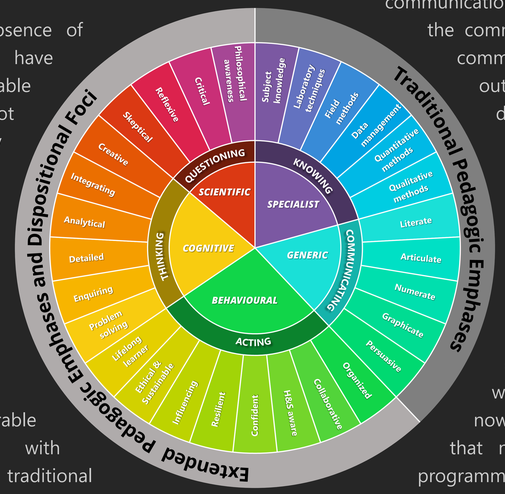
Traditional pedagogic approaches, in the sciences, have focussed on developing subject or disciplinary specialist knowlege, and allied technical skills. The word cloud (above and to the right) is based on analysing 224 module titles from eleven undergraduate geoscience degree programs, from a number of universities in the UK. They were found by a WWW search for "undergraduate geoscience degree". It highlights the knowledge and technical skills focus of the structures of the reviewed programmes.



This is not to suggest the absence of support for developing, what have traditionally been called transferable skills. These are the skills not directly linked with disciplinary knowledge and techniques, but which it can be reasonably expected all higher education graduates to have. However, it does perhaps suggest how important they are considered to be in comparison with specialist disciplinary outputs.

Almost invariably, these transferable skills have been associated with communication. These two traditional elements, subject specialisation and communication, are presented in the dark grey sector of the sunburst diagram - labeled "Traditional Pedagogic Emphases". The scope of such ancillary educational outcomes needs to be extended if the next generation of scientists are going to be able to rise to the new challenges they face.

Simply being an expert in a discipline is no longer enough, if we are to address the many wicked problems we face - from multi-drug resistant bacteria to climate change. Graduates need to not only understand their discipline, but also to be able to communicate their experise to a wider audience, participate in the public realm, advocate for evidence-based policy, and challenge beliefs founded on dogma.



Although, communication skills have formed the backbone of the 'transferrable skills' idea in the past, it has focussed on communication within the discipline, and within the community of practice. The ability to communicate, as a generic learning outcome, was strongly bound to a discipline.

Parks (2018) emphasises the increasing importance of, and need for specific training in, science communication. This call is further complicated by the post-normal science context in which many current scientific endeavours, which address the wicked problems that confront us, now take place. Parks (2018) found that none of science communication programmes she reviewed, focused specifically on the concerns and rhetoric of post-normal science.

The traditional deficit model of science communication is increasingly considered outmoded and inappropriate (Demeritt & Nobert 2014), and science communication has come to be considered a dialogic process. What has changed more recently, is the scope of the conversation, which now incudes not only the findings and processes of science, but also the defence of science itself.

Introducing the new scientist...

The (brave) new scientist is a socially engaged, technically competent subject expert, who behaves ethically, and is a persuasive communicator and reflexive professional.

This is where the elements of the sunburst identified as "Extended Pedagogic Emphases and Dispositional Foci" become important. These focus on professionalisation through the development of behavioural and cognitive competencies. They also aim to faciltiate the enculturation of key elements of the ethos and philosophy underpinning scientific thinking.

The sunburst diagram is devised as a curriculum and assessment planning tool. Specific pedagogic approaches are not suggested. But, it has been used particularly effectively in contexts focussed on longitudinal curricula, problem-based learning, and authentic assessment approaches. The level of a specific educational instance will determine which of the individual elements or areas are emphasised, although there is a general progression in complexity moving clockwise around the diagram, which moves from factual and technical outcomes through professional behaviours to higher order thinking.

If the scope of what it means to be a scientist is changing, approaches to the training and educating scientists also have to change. There is a fourfold imperative to this. Firstly, it is a responsibility we, as educators, have to our students - who have to be able to operate effectively in this new challenged and challenging context. Secondly, we have to ensure that our students meet the expectations of potential employers. Thirdly, we have to meet the expectation of students that they will, having graduated, be able to compete successfully in the job market. Finally, and most importanlty, it is a responsibility we have to the scientific pursuit of knowledge itself.

References:

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