Science education: The urgent need for critical reflection

AUTHORS:
Peter Krumm
Rudi Kimmie

AFFILIATIONS:
UNITE Programme, University of KwaZulu-Natal, Durban, South Africa

CORRESPONDENCE TO:
Rudi Kimmie

EMAIL:
kimmier@ukzn.ac.za

POSTAL ADDRESS:
UNITE Programme, University of KwaZulu-Natal, Howard College Campus, Durban 4041, South Africa

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We are in crisis – not only in South Africa, but around the world. We are experiencing an educational crisis (high failure and dropout rates), a social and moral crisis (crime, corruption, poverty and unemployment), and a technological crisis (depletion of mineral and energy resources and environmental pollution). This situation should force us to reflect on the world, how we live, our actions and our roles and responsibilities towards one another and the environment. It is the technological crises which require scientific and ethical solutions. Thus we are challenged to produce scientists and engineers who reflect critically and contemplate deeply on how we apply our scientific and technological knowledge in pursuit of social and economic development.

It is widely accepted that quality of a nation's higher education and its economic progress are correlated. Hence education, specifically higher education, plays a powerful role in emerging economies where life opportunities are intricately dependent on educational qualifications. In the South African context, science and technology are assumed to be central to improving quality of life and accelerating economic opportunities. However, despite elevated exposure, not only do the failure rates at higher education institutions remain high, but social problems of conflict, hunger, unemployment, ecological destruction and disease are expanding at an alarming rate. These escalating problems reveal critical gaps in the teaching, learning and application of science, especially of physics. A critically informed teaching and learning approach provides the ideal opportunity to resolve the above crises. However, what is needed is a transformation in the consciousness of the learner. This transformation should enable learners to take complete ownership of the learning process through interrogative, critical and reflective thinking.

The vital need for a critical science educational praxis

Science knowledge must, and can, play a role in preparing students to become critical and responsive citizens. The 'body' of physics stands firmly on two 'legs': *application* and *contemplation*, both of which are essential.

Rote and passive learning, which is practised at school and is expected by many to be continued at university, might help students pass exams but does not prepare them to manage their lives and careers, let alone to contribute to finding solutions to our problems. There is a common belief amongst students which is that if shown many numerical examples of how to solve physics problems they will acquire subject understanding and learn how to pass the exam. Experience has shown this belief to be a misconception. In the words attributed to physicist Erwin Schrödinger, 'It is the object of physics, and of physics calculations, not so much to obtain a numerical answer but to gain insight.'

Application is one of two vital pillars on which physics rests. Although students have to learn how to apply their knowledge by solving problems, this process has to be pursued within the epistemological framework of reflexive cognition. It is through *doing* that we learn, and this *doing* must imply *thinking*. Therefore the other vital pillar that physics rests on is *contemplation*.

Physics, like religion, is an attempt to understand or make sense of the world. This contemplation, the attempt of making sense of the world, the search for answers to questions of 'how' and 'why' and 'could it be different', is at the forefront of physical enquiry and precedes any applicability. For instance, Einstein's special theory of relativity, which expressed his belief that all inertial frames moving or at rest (whatever that may mean) are physically equivalent, was sheer contemplation. However, this thought led him to the formulation of his most famous equation, $E=mc^2$, which opened the door to thorough investigations into the nature of the nuclear force and of nuclear energy. Reckless application of the theory resulted in the development of nuclear bombs, such as those dropped on Hiroshima and Nagasaki. Although well known, it is often forgotten that when 'talking physics' we are talking life and death. With the power bestowed on human beings by the ability to decipher the writings of nature, comes responsibility – a recognition never too early to be passed on to our students.

Reframing science education

Students of physical science should fully understand their purpose for pursuing a higher education degree in the sciences. They are at university not only to acquire a passport to a career in science and technology by passing the required examinations, but also to be shaped for a meaningful, creative and productive life, which not only carries rewards but also responsibilities.

Integrating the two pillars – contemplation and application – in the higher education formal curriculum requires a fundamental epistemological shift. Undoing some of the reactive practices of rote learning and learning for facts only, have stifled the naturally curious minds of young learners. Hence it is imperative that teaching and learning must be reoriented away from its current focus of passing exams, towards the shaping of consciousness that understands knowledge in relation to its relevance in the world. Contextual learning, analysis and critical reflection must underpin all teaching and learning praxes.

Although the above applies to all science students, our main concern rests with physics and engineering students. The world crises require political, scientific *and* technological, that is engineering, solutions. Thus, rather than producing highly qualified scientists and engineers who know how to follow every instruction, we must produce original thinkers, who dare to question the system and challenge established assumptions – people with imagination capable of contributing to finding solutions to our problems.