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In Praise of a Deficit Model

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Recent criticism of deficit model thinking has rightly drawn attention to its insidious tendency to embed privilege and perpetuate bias and injustice. This paper argues that there are some areas of the curriculum where it is necessary for a teacher to identify deficits of skill or knowledge that act as a block on the student's academic progress in a particular disciplinary context. The parts of the curriculum for which this is true are highly discipline dependent. A particular example, the place of mathematics in the physical sciences, is discussed at length. This paper calls for caution when criticising colleagues across disciplinary boundaries.

Introduction

In this paper I argue that there are certain areas of the curriculum, namely those where a lack of certain skills or knowledge would prevent a student from developing and progressing in their chosen field, where it is appropriate to think in terms of deficit. I illustrate the point by discussing the role of mathematics in physics education because, first, this is my area of professional expertise and second, it is widely misunderstood by colleagues from arts and humanities disciplines. I hope by doing so to demonstrate that caution is required when criticising the deficit model and that uncritical condemnation of deficit thinking should be avoided, particularly across disciplinary boundaries.

Mathematics has a central place in physics education and a deficit of maths skills is important for both student and staff to recognise. Different skills play a corresponding, central role in other disciplines, particularly those with a strong paradigm (Neumann 2001), and it may well be that responsible educators should cautiously recognise deficits without falling into the trap of defining the student by the deficit.

The Deficit Model

There has recently been much criticism of deficit model thinking which characterizes students in terms of a lack of academic and cultural resources that they need to fit in and succeed. In this model the role of education is to 'fix' the students by addressing their inadequacy. Criticism of this approach has highlighted its tendency to perpetuate stereotypes and promote injustice and the stratification of society.

As university student numbers have increased, so has diversity. Large numbers of students are described as 'non-traditional', drawn from 'disadvantaged' backgrounds and are widely perceived as 'under-prepared' for higher education (Smit 2012). Many such students are found on foundation year programs that are designed to remedy this lack of preparation in the name of widening participation. The problem with the dominant deficit narrative is that it tends to blame the individual student for a lack of desirable characteristics while deflecting attention away from social injustice within the very systems of higher education (Biggs and Tang 2011).

Deficit model thinking can lead to unconscious bias. Gorski, (2017, ch. 5) has a helpful discussion about stereotypes regarding the "mindset of poverty" and assumptions that are often made about the poor. We all participate in faulty generalisations, often unconsciously, and when we apply stereotypes to groups of people we perpetuate bias and inequality. We latch onto evidence that supports our biases and are blind to data that challenges them. Conscious reflection on such deficit model thinking can be a valuable tool to help educators uncover their own internal biases and counter the resulting injustice.

Disciplinary Differences

David Pace, an early proponent of the scholarship of teaching and learning (SOTL), wrote an influential essay, 'The Amateur in the Operating Room' (Pace 2004) calling for reform of teaching practice in his own field, namely history. He argued that history professors were expert historians but when it came to teaching they were mere amateurs. He urged that the same evidence based, critical approach that informs academic research should be applied to teaching and learning. Pace and other early SOTL reformers sought to destroy the idea of the 'sage on the stage' lecturer who sees his or her role as merely transmitting content into the minds of receptive students. These ideas and the shift from teacher-centred to student-centred learning are now mainstream.

Pace and other proponents of SOTL immediately recognised the significance of disciplinary differences for pedagogy. Salvatori and Donahue (2002) argued:

> We need a culture of teaching as intellectual work – work that can be theorized, work whose parameters and conditions of possibility can be analyzed and evaluated in accordance with formally articulated standards, work that can be interpreted within a framework of disciplinary knowledge and modes of inquiry.

Or, as Pace put it, "at the core of the entire project of a scholarship of teaching and learning is the belief that disciplinary thinking is crucial to learning" (Pace 2004).

A small but significant body of research has examined how disciplinary differences lead to different teaching and learning practices. Neumann et al. (2001; 2002), following Biglan (1973), group disciplines into "hard pure, soft pure, hard applied and soft applied, each manifesting its own epistemological characteristics."

> Hard pure knowledge (of which physics and chemistry are exemplars) is typified as having a cumulative, atomistic structure, concerned with universals, simplification and a quantitative emphasis. … Soft pure knowledge (of which history and anthropology offer cases in point) is, in contrast, reiterative, holistic, concerned with particulars and having a qualitative bias. There is no sense of superseded knowledge, as in hard pure fields. (Neumann et al. 2002)

In this scheme, hard applied knowledge would be typified by engineering; subjects concerned with professional practice such as education or management studies would represent applied soft knowledge. Neumann discerns differences between hard pure and soft pure disciplines in regard to curriculum, assessment and what she calls the "main cognitive purpose" of the discipline as well as characteristics of teachers, types of teaching methods and implicit requirements of students.

> Hard pure disciplines are expected in part to enhance the students' powers of logical reasoning, and in particular their capacities to apply and test out ideas in congruity with linear form of argumentation. The ability to understand and interpret theory is a related purpose. Facts, principles and concepts hold a prominent place in the acquisition of knowledge … as do classification, categorisation and description of the material world. The intellectual skills developed in the course of degree work are predominantly specific and subject related, rather than generalizable outside the disciplinary context ... The emphasis in soft pure knowledge is typically on a broad command of intellectual ideas, on creativity in thinking and fluency of expression. Powers of analysis and synthesis are in their turn expected to have a wide rather than a limited application. A typical claim concerning the outcome of degree courses relates to the achievement of personal growth and the formulation of an individual interpretation of the world of human experiences. … Various studies have shown the high value placed on broad general knowledge, character development, critical thinking and creativity. ... Arguably, soft pure subjects enhance students' ability to debate perspectives while hard pure ones develop a capacity to use accepted scientific viewpoints. (Neumann et al. 2002)

Lattuca and Stark (1994) contrast disciplines "where a common paradigm is accepted" and curricular coherence is valued with those that value multiple critical perspectives and are suspicious of coherence.

Thinking like a physicist: the role of models

If education is about learners adopting disciplinary ways of thinking then a physics education is about students learning to think like physicists. In the following sections I focus on the role of theoretical models, particularly mathematical models, in a physics world view because I am a physicist and that is what I know best; it is not meant to imply any priority or superiority over other subject areas. I aim to demonstrate that the pivotal role played by mathematics in a physics world view requires a kind of deficit model thinking in a limited context. There may well be aspects of education in other disciplinary contexts where it is also appropriate to think in terms of student deficit but I do not make that case here. I hope this discussion encourages reflection across a wide range of educational contexts.

For the sake of simplicity and clarity of argument, in the following discussion I assume a critical realist stance to describe the relationship between theory and the natural world (Ponterotto 2005). This is not central to the argument regarding the role of maths in science education from other epistemological positions. The aim of the physical sciences, and physics in particular, is to create theoretical models that correspond to the physical world in the sense that they not only describe known facts but also make predictions that accurately foretell the results of future experimental observations and measurements. Science owes its technological success to this ability to describe, predict and control natural phenomena. Its cultural prominence comes from the seductive promise of explanation and meaning offered by theoretical explanations.

A scientific model is not physical reality itself but rather a theoretical construct that corresponds to nature to a greater or lesser extent. It acts as a lens though which nature is viewed that focusses, clarifies, makes sense of – and yes, sometimes distorts – our perception of the physical world. Similarly, a model is a window that both frames and limits our perception of the world on the other side. By framing our view it gives context and meaning as it draws attention to certain features and their relationship to each other and yet at the same time it also restricts and limits what we see. In these metaphors, the lens and window are not themselves the focus of attention but rather the thing through which the world is viewed.

Mature scientists inhabit this model-based framing of physical reality and instinctively understand nature in terms of physical concepts. They will see forces, electrical charges, space-time, acceleration, band-gaps, and waves everywhere without conscious awareness that these are features of the scientific models that mediate access to reality rather than features of that reality itself. This is what Polanyii describes as "tacit knowledge" (Polanyi 1967; 2009). He uses the analogy of a blind man's probe to illustrate how our attention can be extended through the use of tools and how a skilled user becomes unconscious of the tool. Mastery of the tool becomes tacit, allowing focal attention to be on the thing acted upon. In a similar manner, experienced scientists will usually be unconscious of the mediating role of the model as they think about the natural world in terms of the concepts and features of the model. However, if required they are able to step back and consciously focus on the model itself and its mediating role. They can take off their spectacles and direct attention to the lenses if the need arises.

The best theoretical models are mathematical in nature because when the description of physical phenomena is encoded in mathematical equations, the predictions of the model are numerical in nature and can be more precisely tested. For the best models there is staggeringly precise agreement between the theory and observation. The relationship between mathematics, a deeply creative and human artefact, and the physical world of nature is puzzling and has exercised the minds of many great thinkers from Galileo onwards. It is well summed up by Wigner (1990) in his article 'The Unreasonable Effectiveness of Mathematics in the Natural Sciences' where he reflects on the fact that mathematical concepts permit an "unexpectedly close and accurate description" of natural phenomena: "The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve".

A key aspect of disciplinary thinking in the physical sciences is therefore mathematics, which is both knowledge and skill. It is knowledge in the sense that the scientist adopts and internalises relationships among abstract mathematical objects and comes to grasp a complex web of logical connections between them. In this way the scientist comes to appreciate the beauty and coherence of maths for its own sake in much the same way as a mathematician does. For the scientist, however, maths also represents a skill to be mastered in the sense that it is used as a tool for exploring problems and puzzles related to the physical world, problems that are not, on the face of it, inherently mathematical.

Learning to think like a physicist: physics education

Learning to think like a physicist is not easy. Of course it is certainly true that adopting disciplinary modes of thought is a challenge in any subject and all higher education is intellectually demanding. Physics students, however, face two unusual challenges: physics theories often do not correspond to our intuition about the world, and physical models are fundamentally mathematical.

Thinking like a physicist is an unnatural way of thinking about the natural world. Many of the concepts familiar to physicists and fundamental to the way they perceive reality are properties of their theories and models rather than of reality itself. The student has to undergo a long process of wrestling with the theory and applying it to multiple scenarios in a controlled environment by means of practice questions in order that the scientific model is internalised and becomes part of the learner's world view. Furthermore, physics theories are often counterintuitive and contradict naïve intuition about the way things work. For example, the way physical objects move under the influence of forces is not at all instinctive but plays a central role in Newtonian dynamics. Before Newton, everyone 'knew' certain things about the way objects move. For example a moving object will eventually stop unless there is something pushing it along. This 'fact' is instinctively understood by almost everybody and corresponds to our daily experience of ordinary objects. The problem is, when carefully tested against well defined experiments, our instincts turn out to be wrong. This means that in the physical sciences where disciplinary thinking is governed by an accepted paradigm, the students' prior experiences of the world often result in wrong concepts, misperceptions and misunderstandings that need to be trained out of them and replaced by the accepted disciplinary paradigm. This is one of the key roles of science educators and clearly contrasts other disciplines that lack a strong paradigm and instead value multiple critical perspectives (Neumann 2001).

Mathematical models are central to disciplinary thinking in physics. It is essential that physics students attain a certain level of mathematical proficiency because that is the means by which they learn to think like physicists. Without mathematical competence much of physics would be entirely inaccessible.

Two cultures today

Anyone teaching at a university will be acutely aware of wide cultural differences between different faculties. Colleagues from the sciences and humanities sometimes view each other with mutual incomprehension and suspicion. From the humanities, science can be seen as technocratic and emotionally detached, teaching merely 'facts' and technical exercises and lacking in critical rigour. On the other hand some scientists look down on the humanities as merely subjective, fragmented and incoherent. The "two cultures" debate sparked by CP Snow (Snow 1990; Leavis 1962) still has resonance today (Cordle 1999; James 2016). It is essential that educators should be wary of making value judgments across disciplinary boundaries.

Scientists are sometimes accused of merely teaching a set of tricks and mathematical techniques for solving puzzles in exam questions. I, myself, have been told that if we ask questions for which there is only one correct answer then we cannot be assessing higher order thinking skills or requiring critical thinking. I believe that this (mis)perception of science arises from a misunderstanding of the role of mathematical skills, which we teach not for their own sake but because they are essential tools that must be mastered for the student to internalise the scientific world view. The window through which we understand reality is inherently mathematical and our aim as teachers is to bring the students to the point where they have internalised the mathematical tools so that they are part of the tacit knowledge that facilitates focal, model-mediated critical thinking without getting in the way. At first, while students are mastering these tools, the focus is on mathematical details and it does sometimes seem as though correctly answering mathematical questions is the point. But it is not! Ultimately the students must master the maths in order to internalise the mathematical models so that they can think like physicists.

A Place for Deficit Thinking

In light of the above discussion it seems to me that a limited form of deficit model is appropriate at this point. Because of the central role played by mathematical thinking, a learner who has a deficit in his or her mathematical skills will be prevented from making progress in the physical sciences. Presumably, the students who have chosen to enter a STEM foundation year want to progress in science or engineering. A deficit of mathematical skills will prevent this progress and frustrate their desires. When gaps arise in their mathematical skill set it is therefore surely the job of the teacher to identify the deficit and seek to remedy it. Crucially, identifying a deficit of essential skills or knowledge does not have to mean that the student is *defined* by this.

An analogy can be drawn with the doctor-patient relationship. In the medical model, disease could be regarded as a deficit of health, a dis-ease. The doctor's role is to diagnose and attempt to treat this deficit because it prevents the patient from fully experiencing life. However, doctors, particular general practitioners, value and practise holistic medicine. That is to say, they strive to treat the patient as a whole person. The patient *suffers* from a disease but is not *defined* by it. A good doctor will see the patient as fully human, shaped by their own unique history and complex social factors. Their own desires and aspirations are central to the course of treatment that is ultimately prescribed. The days of a paternalistic doctor dictating a course of treatment without considering the patient's wishes should be consigned to the past. Despite this valuable emphasis, it remains true, however, that a doctor who refused to diagnose and treat a disease because they prefer to focus only on health and wellness would be regarded as professionally negligent. Likewise, an awareness of the social factors and injustice that contribute to the patient's condition do not absolve the doctor of responsibility to treat the disease.

Conclusions

In higher education, particularly foundation years, students are drawn from highly diverse backgrounds. Their own experiences of life are likely to be different from their teachers'. It is therefore essential that teachers reflect on these differences and attempt to become aware of, and counter, their own biases. Challenges to the deficit model offer a helpful framework in this context and remind us of the complex social factors and often injustice that have shaped our students. This prompts us to practise holistic teaching in which we fundamentally regard our students as fully human. Their own desires and motivations are central to learning. We should not define our students by what they cannot do. However, despite this valuable emphasis it remains true that in certain contexts a deficit of essential knowledge or skills will prevent the student from progressing in their chosen field of study. This deficit must be diagnosed and treated and an educator who refused to do so would be professionally negligent.

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