Watching the pendulum swing: changes in the NSW physics curriculum and consequences for the discipline

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For the first timein 17 years, the Higher School Certificate (HSC), New South Wales'(NSW) flagship course that wraps up 13 years of schooling for around 76 000 students each year, is undergoing major changes. As part of the reforms, many courses will be rejuvenated, removed or newly created in an effort to reflect achangingworldandworkplaceandto'increasestandards'[1]. In this article, wediscussthenatureand consequences of these changes in terms of HSC physics specifically, whilst commenting more generally on how physicists can positively influence the science education space.

Australian Science

The excitement around and appreciation of the necessity of Science or STEM (Science, Technology, Engineering and Mathematics) for the country's future [3, 4] seems a sentiment not fully reflected in our schools and universities. In fact, evidence from several different sources is telling us that students are losing interest, performing worse and shunning STEM-related degrees and careers. For example, the Programme for International Student Assessment (PISA) shows Australian students are slipping behind their international peers in both science and mathematics [5, 6]. Results from TIMSS (Trends in International Mathematics and Science Study) show that compared to the top five performing countries, only half as many Australian year 8 students achieve the highest performance band in science (11%, compared to 23%) and this is worse at 9% (compared to 41% in top band) for maths. TIMSS also tells us that that student interest in science and maths declines throughout schooling with a healthy 55% of students 'liking' science in Year 4 transforming into a disappointing 25% in year 8. This is not to mention the teaching profession, where one in five science teachers are not technically qualified to teach science and 40% of schools report they have difficulty filling maths and science teaching positions. Nationally, there has been a decline in participation in almost all science subjects (apart from Earth and Environmental Science) between the years 1994-2013, with physics participation decreasing by 5% (Figure 1). Physics is easily the most 'extreme' example in the sciences; with lower enrolments (both high school and University), a more skewed male to female ratio and the enduring reputation for being 'hard' [7].

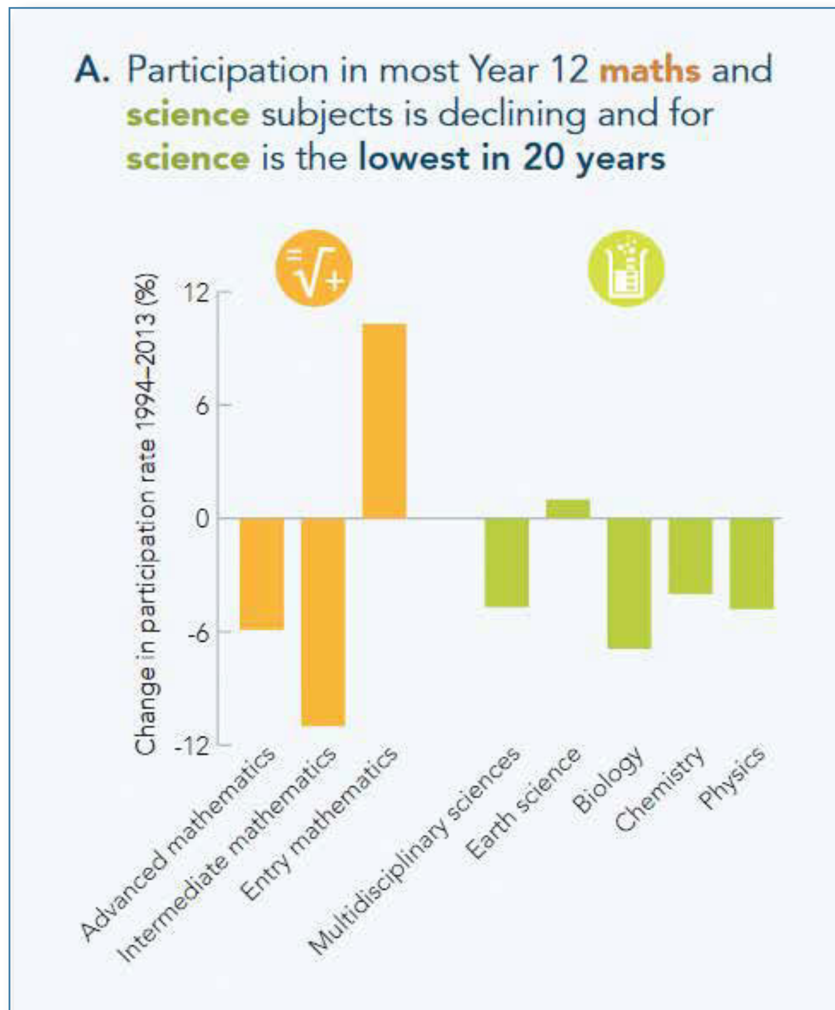


Figure 1: Enrolment trends for Australian high school science subjects [2]

Watching the pendulum swing (continued)

DIMENSION	2001 (CURRENT) SYLLABUS	2018 (NEW) SYLLABUS
Rationale	Reduced content, embedded 'nature and history of Science' and contexts, intended to increase accessibility to wider group of students	Increased mathematical content, reduced 'social' dimension, removal of contexts, opportunities for authentic practice of science (depth study), reduced opportunities for 'rote learning'
Organisation	Content organised under 'Prescribed Focus Areas' (e.g., Moving About, From Ideas to Implementation), separate 'option' topics (e.g., medical physics, geophysics and electronics).	Organised under topics (e.g., Thermodynamics, Advanced Mechanics etc.). New type of content, known as 'depth studies', intended to allow autonomous 'deep learning' of a particular content or skill area. No options
Mathematical Content	Decreased but still prominent (Newton's Laws, Motor Effect, Photoelectric effect etc.)	Increased. Vector algebra in Year 11, derivations across the board, twice as many equations as the current syllabus.
Topics	Cover a broad range of content: e.g., equations of motion, specific scientific breakthroughs and scientists (e.g., J.J Thomson's cathode ray tube experiment and Planck and Einstein's view of science), and social issues (e.g., impact of transistors)	Mostly 'classical' physics topics (waves, mechanics, electricity, thermodynamics) with astrophysics and particle physics becoming part of the core, rather than options.
Assessment	Mixture of school-based assessment and state-wide HSC examination, which contains a mixture of multiple choice, short answer and longer response questions.	Though assessment has not been finalised at the time of writing, it has been conjectured that the essay-type (longer response) questions will be greatly reduced, less opportunities for rote learning are a feature (as an overall philosophy among all new syllabuses in NSW).

Table 1: Comparison of the'current'(2001) and'new'(2018) NSW HSC syllabus

Syllabus changes and consequences

Though there are some who debate the significance or magnitude of the 'STEM crisis', the value of having strong scientific literacy is clear and the impetus for change is profound [8]. The mechanism most available and possibly influential in affecting students' scientific literacy is the school curriculum and thus, contestations around it have always existed. In an article outlining the history of physics education reform in the United States, for example, Otero and Meltzer [9] demonstrate that from as early as 1880, calls for more 'authentic' studies of science (rather than 'lectures' of 'facts') have featured every few decades in successive curricula reform; at first it was laboratory work, then inquiry, scientific practice, the nature of science, the scientific method, and so on. They also interestingly suggest that *"current reformers have failed to acknowledge similar efforts and issues from previous times."* (p. 54), implying many of these suggested reforms are fundamentally identical, except in name. What we see now in science education reform in Australia, NSW specifically, is an example of such a contestation: a syllabus that is broad in scope, contextualised and focused on the nature and history of science will give way to a modular and mathematical syllabus, focused on 'classical' physics (See Table 1). But it's more complicated than that. Though aspects of the syllabus have become more 'traditional', there has been a stronger emphasis on the scientific practice within the subject (e.g., Depth Studies) and in general across the whole reform (e.g., Extension Stage 6 and the new subject, Investigating Science). The question then arises; what does this change mean and how should we respond to it?

The likely consequences of the new NSW physics syllabus

Contestations around the syllabus are frequent and often quite vociferous, and with good reason; changes in policy do make a

Watching the pendulum swing (continued)

difference. For example, research around the previous change showed that though students understanding of key concepts remained the same, the students from the current syllabus actually demonstrated superior understanding of the nature of physics knowledge when compared to students studying the pre-2001 syllabus [10]. Another piece of research examining the use of technology in teaching and learning in the HSC sciences showed that the use of technology in physics resulted in improved HSC scores, compared to both other science subjects and groups without technologies. Since the physics syllabus recommended or even mandated various technology use, including simulations, and the biology syllabus, for example, does not, it is hypothesised that the effect was based on the explicit presence of these requirements in the syllabus [11].

It has been widely speculated that there will be several knock on effects of the current change. Firstly, with the increase in mathematical rigour, it has been predicted that numbers studying HSC physics could markedly decrease [12]. Abrahams' work on HSC physics persistence shows that one of the key factors is the perception of performance; that is, students that perceive a topic to be one in which they will not perform well are more likely to not continue in physics [13]. The new Physics syllabus, has, in Year 11, all three of topics, mechanics, waves and electricity, that are considered the least likely to result in perceptions of better performance (and hence persistence in the subject).

On the other hand, it has also been anecdotally suggested that the new rigorous syllabus will attract back more able students who currently opt for the humanities to play the 'ATAR (Australian Tertiary Admission Rank) game' (selecting subjects to maximise final marks, an issue that is promised to be rectified in the reforms). Students are most likely to be gained at private and selective schools (with a higher concentration of students with stronger academic ability) and lost from regional, remote and low socioeconomic schools. These schools are already suffering from staffing difficulties and small physics class sizes, meaning that even if a student is capable of studying the subject, they may not be able to. Beyond the issues this raises for participation in the future workforce, this does nothing for inclusivity in a subject which is already known to struggle to attract minorities [14].

The changes offer substantial challenges for teachers. The new content, e.g. thermodynamics, will be new to many physics teachers, even experienced teachers. However, unlike the introduction of the new K-10 Australian Curriculum, there is no additional funding for the roll out of the new HSC syllabuses. Physics teachers need to be taught the new content and associated experiments in an already time-restricted environment [15]. Recalling our earlier reporting of the state of teacher qualification and shortages, where over 20% of physics teachers are teaching out of specialism i.e. are not physics-trained, and considering nearly half of all physics teachers retiring over the next 10-15 years [16], this is a serious concern.

Going a little deeper

Though the syllabus will have some tangible and possibly concerning consequences, the teaching of physics is actually notoriously quite resistant to curricula changes. Carlone explains that the 'prototypical' view of physic as being 'difficult, hierarchical, objective' is maintained and reproduced despite policy changes, and that this characterisation undermines inclusivity [17]. Physics is considered the 'prototypical' science both from within, where it is referred to as the most 'fundamental' [18] but also from the outside, where it is considered 'pure' [19], 'abstract' [20] and 'hierarchical' [21]. So despite calls for broader, contextualised ways of teaching physics, a certain rigidity in what physics is and is not seems to persist. This rigid view quite possibly underlies the decades of unsuccessful reform of physics education and is perhaps why physics is suffering particularly badly in the current crisis.

It is interesting to uncover these tensions over the decades. A fascinating excerpt from an early 20th Century policy discussion piece, for example, demonstrates that even at that point in history, the 'new' approach to teaching physics was one that:

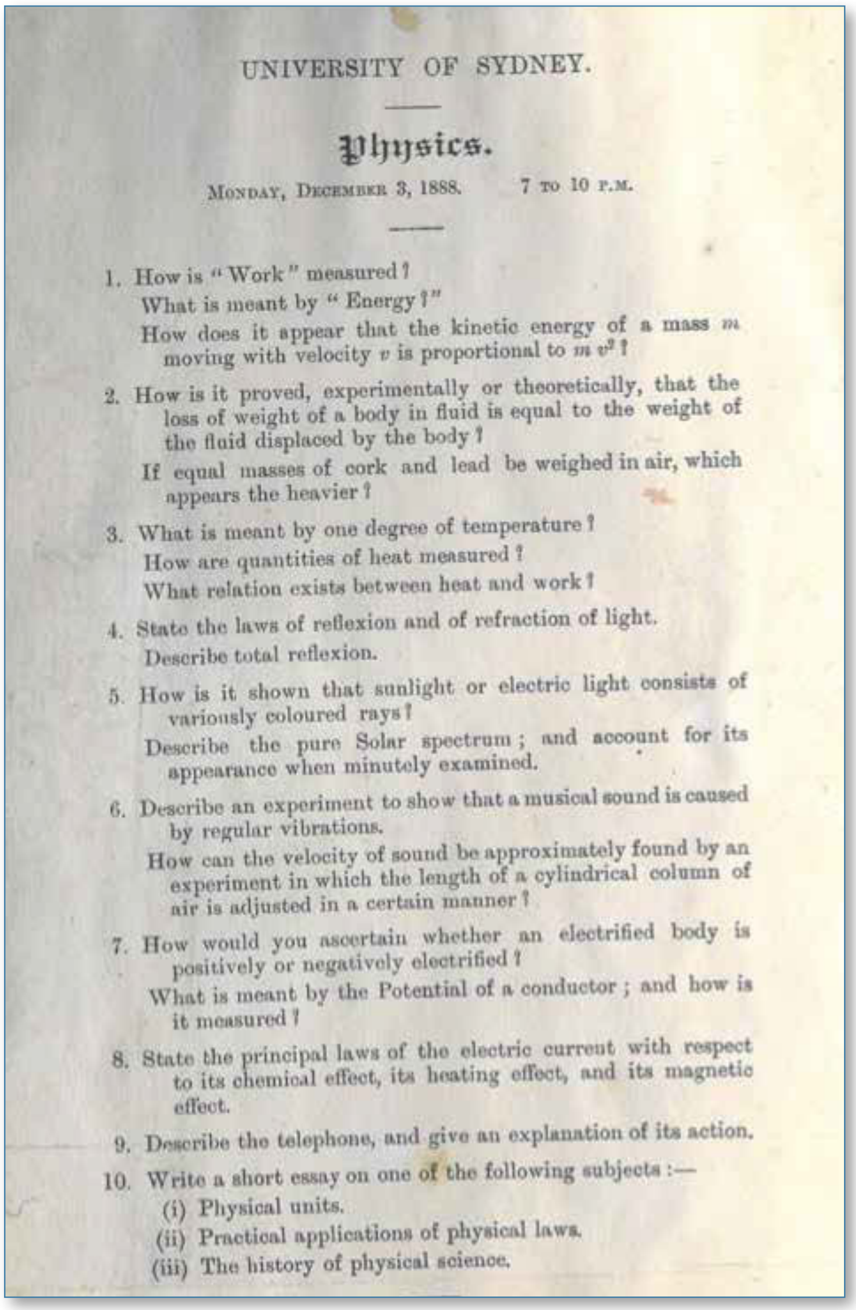
"emphasise(d) "the development of habits of scientific thought" and "the method by which science obtains its results" rather than "more or less scattered facts and theories" taught in such a way that they could only be committed to memory." (quoted on p. 53 in [9])

Exam questions from The University of Sydney (Figure 2), a university known for its excellent reputation in the sciences, show that 'essays' and the history of physics were considered to be extremely important as far back as 1888.

In 2001, the syllabus change heralded a new era of incorporating the nature and history of science after decades of work and substantial robust research in the local context [22, 23]. However, in the wake of the new syllabus, the old has been branded 'soft', lacking in substance, weighed down by unnecessary history and sociology and, very unfortunately, 'feminine' [24]. Instead, the new syllabus signals a 'return to basics', increased rigour and back to form [1].

Why are the holistic, contextualised, humanistic and social qualities placed in opposition to rigour and mathematics? And why are these currently considered 'bad' and 'good', respectively?

Watching the pendulum swing (continued)


UNIVERSITY OF SYDNEY.

Physics.

MONDAY, DECEMBER 3, 1888. 7 TO 10 P.M.

1. How is "Work" measured?
   What is meant by "Energy?"
   How does it appear that the kinetic energy of a mass m moving with velocity v is proportional to $m v^2$?
2. How is it proved, experimentally or theoretically, that the loss of weight of a body in fluid is equal to the weight of the fluid displaced by the body?
   If equal masses of cork and lead be weighed in air, which appears the heavier?
3. What is meant by one degree of temperature?
   How are quantities of heat measured?
   What relation exists between heat and work?
4. State the laws of reflexion and of refraction of light.
   Describe total reflexion.
5. How is it shown that sunlight or electric light consists of variously coloured rays?
   Describe the pure Solar spectrum; and account for its appearance when minutely examined.
6. Describe an experiment to show that a musical sound is caused by regular vibrations.
   How can the velocity of sound be approximately found by an experiment in which the length of a cylindrical column of air is adjusted in a certain manner?
7. How would you ascertain whether an electrified body is positively or negatively electrified?
   What is meant by the Potential of a conductor; and how is it measured?
8. State the principal laws of the electric current with respect to its chemical effect, its heating effect, and its magnetic effect.
9. Describe the telephone, and give an explanation of its action.
10. Write a short essay on one of the following subjects:—
    (i) Physical units.
    (ii) Practical applications of physical laws.
    (iii) The history of physical science.

Figure 2: The University of Sydney School of Physics exam from 1888 (see Question 10)

This is the important question to consider. Rather than propagating an erroneous view of physics as 'objective', 'rigorous' and 'masculine', we must instead discuss the nature of a discipline, its values, and its 'epistemology' in curricula reform and in education more generally. Speak to any practicing physicist, for example, and they will tell you that 'mathematics' does not necessarily equate to 'rigour'. A conceptual understanding, and one where equations are understood, rather than algorithmically solved, is instead superior; a view supported by decades of physics education research [25,26]. Furthermore, if the syllabus aims to reflect the scientific practice, essay writing, which is often reported to be the antithesis of Physics, is actually essential; without it, grants cannot be won and physics cannot be done.

Such critical examinations of a discipline/subject, rarely happen but can be extremely insightful when they do. Existing research, for example, shows how a focus on the way physics knowledge is structured can help students overcome misconceptions [27] and explicitly pointing out the characteristics of scientific practices reduces confusion about how science works [28].

What do we do about it?

If we do nothing about the issues raised then the inequity of access to high school physics will be greatly amplified as the regional, remote and low socioeconomic schools struggle further in attracting both students and physics-trained teachers, whereas metropolitan, high socioeconomic and selective schools will continue to recruit relatively healthy numbers of students and trained teachers. Exclusion of females and other groups, who just don't 'see' themselves as physicists, will also likely continue, or even worsen. We can though, do something about this.

Firstly, and practically, universities and institutions can develop online resources and outreach programs for teachers and students, particularly regarding the new content. In addition, teacher professional development courses focused on developing disciplinary expertise can be developed and widely promoted.

On a more 'theoretical plane', though scientists, particularly physicists, tend to commonly avoid 'political' or sociological inquiry, there is no hiding from the fact that the existing contestations, particularly in physics, are already socially charged. The very group (university academics) that call for a syllabus to be mathematical and rigorous will also explain to you that conceptual understanding and appreciation of the context of an equation are just as important. Physics being perpetuated as 'rigorous, mathematical and masculine' is not only halting inclusivity and equity; it's not a true reflection of a discipline which is ever-changing, humanistic, beautiful and, sometimes, subjective. Instead of reacting against the 'socialisation' of physics, perhaps a deeper study of what the discipline is and is not should occur. Maintaining and promoting this conversation, such that all stakeholders are aware of the impending issues, will go a long way to addressing the postulated demise of physics for all in NSW and Australia at large.

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Author biographies

Dr Helen Georgiou is a lecturer in science education and former high school physics teacher. Helen's research focuses on how to describe and develop student understanding in science, particularly in areas which consistently cause problems for students. One aspect of Helen's current research draws from sociology in using Legitimation Code Theory to explore the nature of scientific knowledge in various educational contexts. This approach is able to make certain knowledge claims and practices more explicit, reducing the risk of misunderstanding and disengagement in science. Other research interests include diagnosing misconceptions, assessing new instructional techniques, and analysing student explanations. She also has an interest in female representation in science (particularly physics) and professional learning through peer observation (in higher education).

Dr Simon Crook has a PhD in Physics Education Research from The University of Sydney. His thesis examined the use of technology in teaching and learning in the sciences. Simon was a high school physics teacher for 15 years and eLearning Adviser for 7 years. He is now a STEM education consultant with his company CrookED Science. Simon is an active member of the USyd Physics Working Party on the Physics Syllabus Change. He contributed substantially to the consultation for the new HSC Physics Syllabus in NSW and has continued the commentary since its release earlier this year.