THE NUFFIELD REVIEW OF
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EDUCATION & TRAINING

ISSUES PAPER 9

APPLIED LEARNING

THE CASE OF APPLIED SCIENCE

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Introduction

Following its three Annual Reports in 2004, 2005 and 2006, the Nuffield Review of 14-19 Education and Training is now producing *Issues Papers* which focus upon specific areas of concern, with a view to widening the debate, testing tentative conclusions and seeking further evidence.

'Pure or Applied'

One such issue is the place of 'applied learning' in meeting young learners' needs, and in particular the place of 'applied science' in the whole curriculum[1].

[1] See Issues Paper 7 on Whole Curriculum. This Paper draws upon the evidence presented at the Review's two-day seminar on Applied Science, September 2007 (www.nuffield14-19review.org.uk)

There is one major reason for this. The determination to make the curriculum more inclusive has challenged the way in which young people are expected to learn.

We're told there's too much academic work, too much teaching of theory that has no practical value or relevance. This leads to the assumption that many young people would learn more effectively if their learning were more relevant, practical, vocational or applied.

Defining terms

But it is easy to get confused here because of the loose use of terms. And indeed the Select Committee protested, in relation to the new Diplomas, that 'it has not always been clear to what extent the new programmes are intended to be vocational or applied, or to serve a more general

The Nuffield Review is an independent review of all aspects of 14-19 education and training: aims; quality of learning; curriculum; assessment; qualifications; progression to employment, training and higher education; providers; governance; policy. It has been funded for six years by the Nuffield Foundation, beginning in October 2003. Its reports and papers are available on the website www.nuffield14-19review.org.uk or from info@nuffield14-19review.org.uk.

purpose'[2]. 'Applied' means something different from 'vocational', 'practical' or 'relevant', although there may well be much in common between each of these.

Therefore, the case of 'applied science', now well established in schools, is important to the Review for two reasons.

First, it illustrates a particular kind of learning, a way in which knowledge is acquired and understanding developed, which has implications beyond science education itself. Perhaps we might equally talk of 'applied maths' or 'applied humanities'.

But, second, in addressing its central question, *What counts as an educated 19 year old in this day and age?* the Review believes all young people can and should gain scientific understanding of things which affect their everyday lives. The growing popularity of applied science shows how that understanding can be attained at different levels from the very practical to the highly theoretical.

Notes on the state of science education

This different and obviously popular route into science must be of interest to the government, since it is concerned with securing and increasing the supply of scientists vital to the nation's success. Its Science, Technology, Engineering and Mathematics (STEM) policy framework[3] included policies which would increase the supply of science, technology and engineering skills.

The evidence which underpins the government's concern is seen in the relatively small proportion of A Level students choosing the three main sciences[4]. This means fewer students studying science in Higher Education and, by relentless logic, fewer science graduates returning to teach in schools[5]. In the last few years, several physics and chemistry departments have closed in the universities of England and Wales because of lack of demand for places.

What reasons might be given for this decline?

First, *students think science is difficult*. It has been suggested to the Review that students, in choosing their A Levels at 16, see from the statistics that good grades are less easy to obtain in the sciences.

Second, t*here's not enough practical work in the upper secondary years.* Despite the fact that much scientific activity is practical, practical work plays a relatively minor part in the assessment of science at Key Stages 3 and 4, thereby affecting learning opportunities in the study of science.

Third, *there aren't enough good teachers*. Crucially, there is a shortage of suitably

[2]House of Commons Select Committee Education and Skills, 2007, p.13.

[3]HM Treasury, DTI, DfES, 2004, White Paper, Science and Innovative Framework 2004-14.

[4]The number of A-E grades, as % of the population in 2007, was Biological sciences 6.8, Chemistry 5.2, Physics 3.5 (DCSF, RS database)

[5]See, for full analysis of participation in sciences, the forthcoming 'State of the Nation' Report of the Royal Society on participation and performance in science and mathematics examinations by 14-19 year olds.

qualified teachers in physics and chemistry[6].

Fourth, *students don't know enough about careers in science.* There is ignorance, not only about the range of occupations which need different levels of qualification within science related subjects, but more importantly the type of science knowledge and skills used in these jobs – within, say, medicine and health care, laboratories, food processing, engineering. Those who guide students in their choices need to be fully aware of the career opportunities.

Targets

To improve the supply of STEM skills, in 2006 new targets were set which together were intended to increase in the number of young people emerging from education ready to move on into higher level scientific study: in particular, to

- increase the number of young people taking A Levels in physics, chemistry and mathematics.
- improve the number getting at least Level 6 by KS 3.
- improve the number attaining A*-B and A*-C in two science GCSEs.
- increase recruitment, retraining and retention of specialist teachers of physics, chemistry and mathematics.

However, standing in the way of the educational targets are some familiar obstacles – too few scientists and technologists, the historic and intractable divide between 'academic' and 'vocational', and a similarly persistent systemic failure to provide general scientific education for all young people. One way to deal with all of these would be to create new and more attractive components within science. And applied science, as explained below, might be seen as an attempt to meet some of these difficulties.

Applied science is, therefore, a matter of considerable interest to a review of 14-19 education and training. It emphasises practical and experiential learning and points to the relevance of science to future occupations. At the same time, and importantly, it maintains a route into science in higher education.

Applied Science

The recent introduction of Applied Science in GCSE would claim to have bridged that dualism between the so-called 'academic' and 'vocational'. In so doing, applied science might well provide the model for the new Science Diploma.

Applied Science appeared in new GCSE courses in two stages.

First, in 2003, it was introduced as a Double Award. This was revised in 2006 to meet the new Key Stage 4 programme of study.

Second, in 2006, two of the major Awarding Bodies (OCR and AQA) introduced a single award GCSE Additional Applied Science. OCR's course had been trialled for 2 years as part of '21st Century Science'. Take-up of

[6]See Royal Society Report, 2006, A Degree of Concern? UK First Degrees in Science, Technology and Mathematics,

Edexcel's BTEC First in Science increased dramatically at the same time, as schools in England responded to a new key stage 4 Programme of Study by offering students choice from a suite of science courses.

What does "Applied" mean?

At the beginning of this Paper we set out the apparent difficulty of engaging some students in what seems to be a purely academic study. What, then, is it about Applied Science which meets that challenge?

Detailed examples of what follows are given in Gadd's and Campbell's briefing paper, 'Characterising Applied Science', to the Review Seminar, September 2007[7].

Applied science

- includes understanding scientific knowledge and methods of scientific enquiry which are embodied in techniques used by scientists. These techniques cross areas of application (e.g. in the use of microscopes by public analysts, microbiologists and others).

- develops this understanding through authentic work-related contexts – how science actually works (e.g. a nurse or paramedic dealing with an emergency or the reasoning of a building control inspector when confronted by a contractor's unsatisfactory standards).

- focuses on the people who apply the scientific techniques and knowledge, looking into the thought processes and skills involved (e.g. questioning the theoretical and practical limitations of a given technique that determine its application to different problems).

- provides opportunity for practical problem-solving, emphasising ability to use techniques, skills and knowledge for tackling science-related problems (for example, in the analysis of blood samples in the diagnosis of an illness).

- engages with contemporary scientific issues, especially the relation between science, technology and society.

- requires a high level of numeracy because of the centrality of 'quantity' and statistics in the work related science. Accurate measurement is crucial.

Applied Science is not a second best route for those less able to pursue the single subject sciences of physics, chemistry and biology. Rather does it identify and communicate the key scientific concepts and ideas within the practical context of 'doing science' – emphasising how practising scientists use their knowledge and skills to set about everyday work.

In that sense, calling it applied might be misleading, as though first one thinks scientifically (the academic bit) and then one applies that thinking to practice. Applied science, however, is not that two-stage process. The key concepts are embedded in the practice and techniques, and are to be understood, as one gets deeper into the problems, through ever more abstract 'modes of representation'.

[7] Seewww.nuffield14-19review.org.uk/cgi/events/events. cgi?t=template.htm&a=56.

Such a way of understanding the onset of scientific understanding should not be alien to those who have taken cooking or gardening seriously, and seen that seriousness translated into good domestic science and rural science courses.

Unfortunately, recent decades have seen in schools the demise of much practice based scientific understanding as these pursuits have sought respectability by aping the 'academic science' or by being assessed through written accounts of 'knowing that' rather than practical accounts of 'knowing how'.

Projected Student Demand

Feedback from 21st Century Science pilot schools was very positive, but pointed to a problem of progression to further studies in science[8] - a progression route necessary to meet the increased student interest in science as a result of the new courses. That demand would seem considerable.

The number taking Applied Science (in its various guises of GCSE Double Award, GNVQ Intermediate, BTEC National) has increased rapidly in the last four years – from 21,000 in 2004 to 60,000 in 2007.

	2004	2005	2006	2007
GCSE Ap. Sc. Double Aw.	9000	18000	27000	32000
GNVQ Ap.Sc. Found. /Interm	7000	12000	14000	13000
BTEC Ap.Sc.	500	1000	3000	15000

Numbers have been rounded up or down to the nearest thousand

This number will increase significantly in 2008 as many more students take GCSE Additional Applied Science. A quarter of the total cohort may take GCSE in Applied Science in 2008; possibly as many as 150,000 will be take the equivalent of at least one GCSE Applied Science.

Furthermore, the number taking Applied Science at A Level (having remained constant at about 1600 under Advanced Vocational Certificate of Education) rose to 3700 in 2006 and 5000 in 2007, and is due to increase significantly as a result of the considerable increase at GCSE, thus pointing to a need to address the quality of Applied Science courses at Level 3.

Applied science, therefore, seems to be a very recent success story (though too little recognised) in providing a recipe for meeting the demands of the Government's STEM policy, for encouraging more young people to continue with science post-16, for overcoming the dualism between the academic and the vocational,

[8] Bell, J. and Donnelly, J. (2007) Positioning Applied Science in School: Understanding, Opportunity and Risk in Curriculum Reform, University of Leeds.

and for providing a basis of a general education for all 14-19 year olds, not just (but including) those who wish to specialise in science at an advanced level.

Looking to the Future

Following from what is said above, applied science, especially at Level 3, requires the following:

- well informed guidance and career counselling, pointing to the range of careers and higher education courses opened up by this particular route;
- suitably qualified teachers, both in the particular subject areas, and in the knowledge of authentic workplace practices;
- effective professional development and support for teachers - in online e-learning communities, teachers' centres and professional networks;
- considerable investment in the contexts and resources, which are appropriate for authentic applied work;
- assessment which reflects the practical and experiential nature of applied science, employing the range of techniques available (e.g. work-related reports, portfolio of activities);
- arrangements for moderating teachers' assessments of learning;
- continuity from applied science to single subject and theoretical science, in terms of the concepts and skills embodied in the practice or application of science in real contexts;
- collaborative partnerships between schools, colleges of FE, employers and universities to ensure there is available the experienced technical and scientific staff and real life contexts.

Professional Development

'Effective professional development and support for teachers' requires further emphasis. It is a constant theme of the Review that there can be little or no curriculum development without teacher development – not as 'deliverers' of the curriculum, but as active developers of it. Teachers were central to the successful Nuffield Science reforms of the 1970s and 1980s. Supported by Teachers' Centres, they contributed to the production of resources through which scientific concepts and principles would be manifest in the practice of science. There is now an 'Advancing Applied Science Network', which is aimed at all centres offering GCSE Applied Science.

General and vocational education

There is a problem of perception which affects both recruitment and progression, namely, that applied learning in general and applied science in particular are seen as 'vocational' and for the less able.

But that is wrong. It results from the dominance of that false dualism which begins by putting applied science into a separate category from other areas of science, then goes on to argue for its 'parity of esteem' – an exercise always doomed to failure. Far from occupying a separate slot from within which it must justify its existence, applied science fulfils several roles which between them bestride

all the varying needs of our students. For example.

First, it is rigorous mode of science study.

Second, it attracts into science those who, though able, would not otherwise have been attracted to continue with their science studies to Level 3.

Third, because it can be pitched at different levels of both practice and conceptual complexity, it is also suitable for those who may not be willing or may not be able to advance as far as others.

Seen in this way, applied science, as with other 'applied' or practical modes of learning, is part of the general education for all, providing 'rungs on the ladder' for each, yet for some, an accessible climb to higher performance.

Truly vocational

If we wrest the term 'vocational' free of its baggage of lower-status assumptions, we can see that applied science has a further demanding role. It becomes a good and rigorous preparation for science-related employment for those who do not wish to continue to HE. There is a need therefore to understand better the kinds of occupations which they would be well prepared for.

To this end, opportunities need to be found for visits to science-related workplaces so that the students can see the techniques used by a range of practitioners who do not think of themselves as scientists, and can talk with and observe those who are at the science equivalent of the 'chalk face'.

Perhaps there is need for representative employer bodies, first, to help with the formation and delivery of the applied science (particularly with the development of authentic scientific activities within the respective occupations and industries), and, second, to ensure that employers recognise the work-related nature of the qualifications achieved.

Avoiding the triple-carriageway road

In the attempt to provide a more comprehensive qualifications framework, there is a tendency to create (or to continue with) a tripartite system – the academic, general vocational and occupationally specific tracks. Unless care is taken, applied science (as indeed other areas of more applied and practical learning) could be trapped within that tripartite division as a general vocational qualification. Rather should applied science be seen as the kind of course which transcends that division, and which, in so doing, shows that all can benefit from an introduction to science.

Developing Criteria and Specifications

Criteria for the development of improved specifications of applied science courses at Level 3 (A Level) would need

- to reflect the distinctive nature of applied science, and yet
- to be open enough for local development, especially in the light of local or regional science based employment;

- to provide progression from Level 2 applied science;
- to clarify what kind of knowledge, understanding, skills and attitudes are to be assessed;
- to ensure that progression is possible both to HE science and engineering courses and to specific science based occupations;
- to reflect the interests and motivations of young people seeking to take applied science who otherwise would not continue with science;
- to ensure a 'demanding level' which is comparable with that of the other sciences;
- to specify the key skills to be covered;

Conclusion

The Review is addressing the question, *What counts as an educated 19 year old in this day and age?*

A basic scientific grasp of everyday matters which affect the 'intelligent management of life' would seem to be one aspect of that educated 19 year old – together with the basis for ever deeper understanding for some. And that is what applied science would appear to offer.

At the same time, it provides an illustration of how that dualism between academic and vocational pathways can be eliminated.

Furthermore, it illustrates a way of learning, deeply rooted in the practice of science and in the contexts in which scientists work, which has implications for other areas of the curriculum. Could not the Humanities be approached through the contexts in which issues of human importance are illuminated by the research, deliberations and activities of historians, geographers, anthropologists and others?

The learning experience of all young people would seem to be enriched where that learning grows through the contexts within the world about them and through its application in everyday and work based situations.

This Issues Paper has been prepared in the light of the report of the two day seminar held at the Department of Education, University of Oxford, September, 2007. The Report of the Conference is given on the website. The Paper draws on the work of Peter Campbell, at the Nuffield Curriculum Centre, Ken Gadd, of 4science, and on the advice of Wendy di Marco.

The Review welcomes the responses from all readers. Please write or email comments to richard.pring@education.ox.ac.uk.

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