Advancing
Astronomy and
Geophysics

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The Fruits of Curiosity: science, innovation and future sources of wealth: response from the Royal Astronomical Society

The Royal Astronomical Society (RAS) works to encourage and promote the study of astronomy, solar system science, geophysics and closely related branches of science. It represents more than 3000 members ('Fellows') including scientific researchers in universities, observatories and laboratories as well as related professions such as historians of astronomy, teachers and science writers.
The Society welcomes the Royal Society 'Fruits of Curiosity' inquiry and the opportunity to provide further evidence. Together with this document, we have submitted the results of studies and consultations carried out over the last few years that we hope will help shape the inquiry report.
Our response is aligned to the questions in the consultation document.

The long-term direction of policy for science

1. What role should curiosity-driven research play in the UK science base over the next 15-25 years?

   The RAS believes that curiosity-driven research is an essential component of the UK science base. In the cases of astronomy and space science, the UK has a world-leading research portfolio with highly productive researchers. British astronomers have a strong research record. In the latest set of citation indices, astronomers and space scientists in the UK published more papers and were cited more frequently than any other nation in Europe. Worldwide they are second only to their counterparts in the US (Sciencewatch 2009). UK scientists with training beyond PhD level in these subjects are highly flexible and can be found in a range of professional occupations. The RAS is in the process of surveying Fellows who are doctoral graduates in astrophysics and space science, but no longer work in this field. Preliminary responses show that they hold a range of positions across the economy. They work in areas including adaptation to climate change, teaching in secondary schools, science communication and journalism, engineering, renewable energy, business and technology companies, finance and defence. All cited their PhD training as invaluable in their post-astronomy careers, where they

use their postgraduate skills in mathematics, computing, data analysis and presentation. (Private communications from RAS Fellows, 2009).
Our science also has a strong and positive impact on the uptake of STEM subjects (see q.5).
Consequently, for the primary reason of scientific excellence but also the undoubted economic impact in the broadest sense, the Society believes that investment in blue-skies research like astronomy and space science should be a key component of Government funding priorities in the years ahead.

2. Which elements of policy for science and innovation over the past 10 years have been successful and should be maintained? Where is there room for improvement?

   In 2005 the RAS and Institute of Physics (IoP) published their most recent International Review of Physics and Astronomy. At that time the Review described the morale of the research community as high, reflecting the sustained investment by Government in the previous five years.
   This has been accompanied by international collaboration in major organisations like the European Southern Observatory (ESO) and the European Space Agency (ESA) and the UK has become an attractive place for researchers across the globe.
   By this year the atmosphere had changed somewhat, following the creation of the Science and Technology Facilities Council (STFC) and the ongoing budget shortfall in that Research Council. At the very least the resulting uncertainty is unhelpful and it seems likely to discourage a number of promising early career researchers from remaining in their field, at least in the UK.
   The Society believes that unlike investment for reasons of crisis (e.g. the bailout of the high street banks), a stable research investment environment offers long term dividends. The commitment by the current Science Minister to ring-fence the science budget is therefore very welcome and we urge the inquiry committee to lobby for this to be continued.

3. How will increasing support for science in the US, China and elsewhere impact on the UK's international standing and attractiveness as a place to undertake world-class science?

   It seems inevitable that the UK will find it more difficult to compete if investment in science falls, at least in comparison with other nations. Firstly, financial pressures may ultimately lead to the UK pulling out of international collaborations that allow our scientists access to world class facilities and the data they produce. Secondly, the UK will be allowing investment in science to stagnate against a background of stimulus packages and ongoing to commitment by governments elsewhere.
   We also believe that the deliberate decision not to invest in science in a stimulus package in the last budget was very much a missed opportunity. It did nothing to dispel the idea that a career in finance is the natural option for science graduates and postgraduates, nor did it help the Government to work towards its stated goal of rebalancing the economy.
   Despite these concerns about the future, there is a good deal of evidence that the UK has a strong science base at present and this is certainly the case in astronomy and space science. The Society acknowledges that it is impractical to invest across the board at the level of nations with significantly larger economies. However, we believe that the UK should support and enhance areas of strength, favouring those areas that are essential for the development

of UK science and particularly those in which the UK needs to be competitive in the long term.

4. How should science be governed to maximise benefits to society while acknowledging public questions, uncertainties and concerns?

   The RAS explicitly acknowledges that it is right for central Government to set a framework of priorities for science investment and that those should respond to public concerns. However, we do not believe that an overly prescriptive top down approach to governance will necessarily be effective in identifying research that will meet immediate economic goals. Funding scientific research is not like investing to win Olympic medals, where specific short-term objectives can be set and achieved. In contrast, science advances on a broad front and has indefinite horizons that require a long-term vision.

   The Society believes that it is better to concentrate on funding excellence and on ensuring that the funding is sufficient to achieve the ambitious scientific goals that should be set. We also draw the attention of the Committee to the economic impact of curiosity-driven research, where serendipitous discoveries are made that cannot be foreseen at the outset of these research programmes. Former researchers also use their training to contribute to a large sector of the economy (see q. 1).

   Within the fields of astronomy and space science, the UK membership of large international collaborations like ESA and ESO gives British businesses access to worldwide markets at the cutting edge of technology. Examples include e2v Charge Coupled Devices (CCDs) and other imaging devices used by all major collaborations and space agencies (as well as in digital cameras and medicine), Surrey Satellite Technology and EADS-Astrium, a major global player in the world satellite business.

   Data handling, storage, management and access are areas of growing importance in all fields, and astronomy is no exception. The international astronomical community is developing advanced tools through the Virtual Observatory (and the UK AstroGrid project) with the goal of making the world's huge astronomical data banks transparently useable, in just the same way that the World Wide Web makes documents all over the world feel part of a single interlinked system.

   We cite these examples to demonstrate that assessing societal and economic benefit is no simple matter and to once again state that curiosity-driven research in areas like astronomy should remain a key part of the UK science base.

5. How should we assess the long-term social and cultural impacts of scientific research?

Science, particularly in areas like astronomy, has a high cultural and social impact. The RAS welcomes the decision by BIS and the RCs to include this in their assessment of economic impact.
We also draw attention to the particular interest of children and adults alike in blue skies research referred to time and again by practitioners working in the realm of science and society. Research by Osborne and Collins (2000) and more recently Jarvis and Pell (2005 and 2008) demonstrates that astronomy is unusual in that 'hard to reach' groups like adolescents perceive it positively and that it appears to act as a spur to further study and careers in science in general.
There is undoubtedly a need to commission further research in this area, something recognised in the former DIUS consultation on Science and Society in the UK. Although carrying out such an exercise is not trivial, a starting point would be to assess the long-term effectiveness of the plethora of activities to engage the public in science that are supported by the RCs, learned societies and other bodies.

Investing in tomorrow's talent in schools, universities and in the FE sector

6. How much progress has there been in the past decade in the delivery, content and assessment of education in STEM (Science, Technology, Engineering and Maths) subjects?

At university level there have been few structural changes in the delivery and assessment of undergraduate degrees in physics and astronomy. Physics-based undergraduate degrees are largely 4 years long leading to an MPhys/MSci qualification and this is the normal entry qualification for a research degree, now typically of three and half years' duration. This pattern is different to the 3+2+3 Bologna model which the UK and 28 other European countries agreed to work towards in 1999.
The subject benchmark statement, characterising the skills and achievements that graduates of physics, astronomy and astrophysics degrees should have, was published by the Quality Assurance Agency (QAA) in 2002 and these were reviewed in 2007. Wide consultation and input from a specialist panel convened by the Institute of Physics (IoP) indicated that the benchmark statement required only minor revision although further clarity of some statements and updating to reflect advances in technology-based learning and the addition of statements on ethical behaviour were added (QAA, 2008).
The RAS recognizes the continued concern that there is a lack of consistency in the standard of honours classifications between different subjects within a university, and between universities. It believes, however, that it would be extremely difficult to phase out the traditional honours classifications and some universities would continue to use them, creating even greater inconsistencies. The RAS strongly supports the use of Diploma Supplements and Transcripts that can be used in addition to the honours classification, as they do provide a more informative assessment of a graduate's study programme and achievements. It is not obvious they provide an automatic increase in consistency as Higher Education Institutions (HEIs) use different grading systems to represent performance at module level.
At school level there is mixed evidence of progress. The move to include a wider range of topics, e.g. in Twenty-first Century Science, is not necessarily helpful to the less able children as it includes a very large number of concepts. Teachers and education professionals in the RAS describe an 'over-stuffed' science curriculum at both GCSE and A-level, which removes opportunities

for the most able students to be sufficiently stretched or to study a subject in detail, as there is simply too much pressure to move on to the next topic. School courses may also not be preparing entrants to undergraduate degrees in the way they should. In a recent Higher Education Academy survey (HEA 2008), students and staff agreed that a lack of experience in practical work and problem solving and a lack of mathematical skills were the greatest cause of difficulty for physics students.
On a positive note, the increasing uptake of GCSE Astronomy (more than 2000 candidates enter this examination each year) shows that science subjects in some areas can prove attractive to more enthusiastic pupils, particularly as it is usually studied out of normal school hours (Williams 2008). The National Schools' Observatory and Faulkes Telescope Project have also successfully used direct access to professional research instruments to inform student learning across the curriculum at primary and secondary level.

7. What are the future challenges for STEM education at primary, secondary and tertiary levels? How should these challenges be addressed?

Unfortunately, physics-based subjects have not enjoyed the expansion in HE that has occurred across many other non-STEM subjects and many physics departments have relied on astronomy/astrophysics to maintain undergraduate intake. In 2002 there were 3779 accepted applications to physics courses with a slight rise to 4081 by 2008. Over the same time period the number of accepted applications to astronomy-related courses (most of which are centred on physics degrees) dropped from 993 to 810 (UCAS 2009). Despite this fall, there is much anecdotal evidence that an interest in astronomy has led many students to take (pure) physics degrees. In preparing our evidence for the RCUK Review of Physics in 2008, the RAS received statements from admissions tutors in physics departments across the country supporting this argument and the Royal Society may wish to consider obtaining further evidence of the impact of astronomy and other blue skies topics in encouraging recruitment at HE level.
This interest is easily generated by the natural fascination with the Universe, helped by the wealth of exciting astronomical images available on the Internet, the relatively large number of TV programmes based on astronomy and the large outreach programmes run by most university physics departments that offer astronomy degrees and/or carry astronomy research.
Even with the interest in astronomy, and it helping to maintain the intake to physics departments, it is clear that for many young people a career in STEM subjects is not seen as attractive. There are likely to be many reasons, many being interlinked: poor teaching in key subject areas exacerbated by a shortage of qualified teachers (the University of Buckingham found that half of inner city London schools have no physics specialists – see Smithers and Robinson 2008), STEM subjects are (perhaps correctly) perceived to be more difficult, the lack of obvious career opportunities (e.g. there is not an easily identified physics industry) and the perceived lack of high financial rewards compared to many other professions.
The question of teaching in schools must be the most important factor and is partly addressed in question 8. The perceived difficulty of STEM subjects (particularly physics) clearly links with the quality of teaching but the school curriculum is obviously important (see q. 6).
It is often said that an attraction of a physics based education is that it provides many job opportunities. Although this is essentially true (and in the fields of astronomy and space science there are plenty of examples) they do not seem to be obvious to many young people and the lack of easily identified

physics industries doesn't help; 'what jobs do physicists do' is a question that is often asked. This is supported by the Higher Education Academy survey where 80% of physics undergraduates stated that they do not choose their degree subject primarily for its employment prospects (HEA 2008). Initiatives like the DCSF / Science Council / learned societies' Future Morph website on careers from science may help to tackle this challenge, but it remains to be seen how well this information disseminates to school teachers and hence students.

8. How do we ensure that adequately qualified science and mathematics specialists are attracted into the teaching profession at all levels of education (primary through to tertiary)?

   The Government recruitment campaigns have succeeded in improving the recruitment of science teachers, but there remains a serious shortage of physics specialists. The most recent Training and Development Agency (TDA) census showed that of the estimated final total of 3670 applicants for science teacher training, only 540 were physics specialists (TDA, 2008).
   The RAS therefore strongly supports the continuation and expansion of the financial incentives used to encourage science and particularly physics graduates to consider a career in teaching. The centrally-funded bursaries used to attract entrants to the profession should be supplemented by additional rewards for teaching staff in shortage science subjects like physics – powers available to governing bodies cited in the Sainsbury Review of Science and Innovation (2007) but rarely exercised. However, we also caution that these measures will not be sufficient if those same teachers leave the profession within their first few years of employment.
   One other approach to tackling the shortfall of physics specialists has been to upgrade the knowledge of graduates in other sciences. The Society supports this approach, but also recognises the risk it may not always deliver the enthusiasm those teachers need to be effective.
   The efforts to place physics within a broader degree such as the courses supported via the IoP-led 'Stimulating Physics' initiative (and now subsumed within the national STEM programme) are one example of where this is being tackled with the direct aim of increasing the supply of graduates with at least some specialist physics knowledge.
   The Society strongly believes that work of this kind should continue, with the goal of producing a teaching workforce whose members see themselves as professional physicists as well as teachers of physics. Those Fellows who work as or alongside teachers advise that tackling this and other career status issues is of equal importance to the (welcome) focus on pay.

Building and sustaining research careers

9. How can we make research careers – within academia or industry – a more attractive option for young people, both within the UK system and from abroad?

   Many of those taking a physics-based degree do so because they wish to carry out research. One issue that could make a career in research less attractive is the increasing emphasis on economic return currently promoted by BIS and the Research Councils. In many areas this is difficult to identify because any such benefits will be long term and not predictable. There are also many other benefits that are not readily quantifiable in economic terms but increase

the skills base (e.g. via the supply of highly trained postgraduates into the wider economy.
The RAS has received some reassurance on this issue from senior RCUK and STFC staff through their statements that economic impact will not be a key factor in deciding the allocation of research funding. Nonetheless we wish to re-emphasise that it must remain a secondary consideration to scientific excellence if the UK is to retain its status as an attractive destination for world-class researchers.

10. What sorts of incentives can we develop to keep talented students and postgraduates in science?

    The RAS report "The PhD and Careers in Astronomy in the UK" (2005) studied the prospects for PhD students in astronomy, many of which are likely to apply across science.
    One key issue identified in this report was the time spent by the vast majority of researchers on temporary contracts (often a decade or more) before they were offered a permanent position. The spirit of the EU Directive for fixed-term workers who have been employed for four or more years (i.e. that there is a maximum time period that an employee can be employed on a fixed-term contract) does not appear to be widely adopted and indeed anecdotally it appears some institutions are reluctant to offer extensions to contracts if they are then required to offer permanent positions. This can work to the disadvantage of young researchers.
    If it is not possible for HEIs to be more flexible in their recruitment of permanent staff, then at least those same researchers should be given honest and appropriate careers advice from the start of their PhD. The help available to postgraduates needs to be investigated, so that the 80% of them who will not progress to permanent posts in universities are given the best possible advice on opportunities elsewhere.
    It also remains the case that women are still not progressing to senior levels in astronomy and space science, despite a large increase in the number of female postgraduate students. According to an RAS study, the proportion of female astronomy postgraduates increased from 5% in 1993 to 35% in 2003, but the proportion of female astronomy professors only rose from 2% to 3% in the same period (Walker, 2009).
    One solution to this could be to increase the number of location-independent post-doctoral positions, so that researchers can balance the 'two-body' problem (where both partners are professionals on short-term contracts). RAS Fellows identify the Dorothy Hodgkin Fellowship as a good model for this that could be adopted more widely by the various funding agencies.

11. Does the standard career-track model need to be re-evaluated? Should we take more account of the movement of skilled individuals between academia, industry and business?

    This is partly covered in q. 10. The RAS supports the strengthening of careers advice to postgraduate researchers across institutions. The Society recommends that the 'transferable skills' acquired during a PhD are specifically accredited to allow postgraduates to more easily transfer to industry and business.
    It should also be recognised that scientists can move from research to management and business, but it is generally very difficult to then go back to research at an international level. Those most productive in research need to see a career with continuity rather than it being a start-stop activity.

The ecology of research funding

12. How do we maintain an appropriate balance between curiosity-led, response-mode research and more targeted or programmatic funding?

    *Commenting on the **overall** balance in the science budget is outside of the remit of the RAS. However, we believe that the decision making process for that funding balance should be open and transparent and the reasoning behind the strategies adopted should be made public. The RAS endorses the key principles on this set out in Lord Drayson's recent speech to the Royal Society.*

13. What would an ideal research funding landscape look like in 20 years time? How would funding be allocated? What would the funding bodies look like? How would they relate to one another?

    One specific area the RAS wishes to comment on is the funding of space activity. As a loosely defined partnership the British National Space Centre (BNSC) has not been an effective body in its promotion or coordination of this work. The RAS therefore believes that an independent space agency would be an appropriate response, provided it is not set up using funds that are currently directed towards research.

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