Young Researchers
Reflections from Wellcome on the impact of doing research projects

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The Wellcome Trust is an independent global charitable foundation dedicated to improving health. We support curious and passionate people to explore great ideas in science, medical innovation, the humanities and the social sciences. Education is fundamental to our enterprise because we need a public whose minds are open to science and young people who are interested and enthused to pursue careers in science, including research.

In the UK, and especially in England, school students have limited opportunities to experience science in the way that researchers do. While it is obviously important for students to acquire knowledge and skills, we believe that this should not be at the expense of opportunities to experience authentic scientific research. For this reason, Wellcome has long supported and advocated for independent research projects (IRPs) in school science. We define IRPs in science as projects, usually involving hands-on investigations, in which students or groups of students work independently, supervised by a teacher and/or other adults, on a scientific problem over an extended period.

Wellcome has supported Nuffield Research Placements since 2001 and the Authentic Biology programme since 2008 (see Appendix 1). Both give post-16 students opportunities to do their own independent research, making their own decisions while being guided by researchers from universities and industry, and we have seen how students can reach great heights given the chance to spread their wings. More recently we have developed resources to encourage and support students to place a practical investigation at the heart of their Extended Project Qualifications (EPQs) or other similar schemes.

Unfortunately, IRPs in science are still only done by a small minority of students. To help us decide what more could be done to support their uptake, we needed more evidence, in particular to help us answer the following questions:

1. What is the scope and reach of IRPs in science, in the UK and overseas?
2. What is known about their impact on students?
3. What are the barriers to adopting them in schools and colleges?
4. What more might be done to encourage IRPs in science?

We commissioned the University of York and the University College London Institute of Education to carry out a Rapid Evidence Review to find answers to these questions, and this commentary is in response to their report, which we received in December 2015 and is now available on our website[1]. The Review used an international literature review, interviews with key informants (including teachers and students) and five international case studies to collect evidence and assess its quality. We use this commentary to highlight the important messages from the Review and to discuss the way forward for Wellcome and other organisations interested in supporting IRPs in science.

1 Bennett J, Dunlop L, Knox KJ, Reiss MJ, Torrance Jenkins R. A Rapid Evidence Review of Practical Independent Research Projects in Science. London: Wellcome Trust; 2016. wellcome.ac.uk/IRPevidence

1. The scope and reach of Independent Research Projects

Science IRPs are offered in a number of countries, across the secondary school and college age range and across the scientific disciplines. The older the students, the more independent it is possible for the work to be. The Review judges the quality of evidence on scope and reach to be "good".

In most countries, just a small minority of students do IRPs. An exception comes when IRPs are an integral part of the curriculum, as in the impressive *profielwerkstuk* in the Netherlands (Box 1), where assessed projects are a compulsory part of every pre-university student's leaving certificate. In Scotland, Advanced Highers in science subjects have a compulsory project component. Furthermore, the Scottish Baccalaureate in Science incorporates a more extensive Interdisciplinary Project. The new Welsh Baccalaureate will also require an individual project, similar to an EPQ[2].

More often, IRPs are done outside school hours, in science clubs, through research placements and summer schools, and students may enter their projects for local and national competitions. Students doing IRPs are sometimes supported by a mentor from university or industry.

Some IRP activity, mostly in the USA, has been specifically targeted at groups traditionally under-represented in science, with a focus on one or more of gender, socio-economic status and ethnicity.

Box 1: The Dutch *profielwerkstuk*

The Dutch *profielwerkstuk* ('profile assignment' – a research project) is carried out by all students following the general academic education pathways on track to university (about 47 per cent of the total cohort). The open investigations take 80 hours and are related to one of four 'profiles': Nature and Technology; Nature and Health; Economy and Society; Culture and Society. With 40–45 per cent per cent of these students choosing one of the Nature (STEM) profiles, almost 20,000 students are doing STEM investigations, around 80 per cent of which are practical. Most investigations are carried out at school, some at universities or industries. Most projects are done by two or three students working together.

Often students present their work at school for other students and parents, and there is a national competition run by the Dutch Royal Society. Last year, the three winners of the Nature and Technology profile were all based on original practical work: Bend it like Beckham, whitening toothpaste and the future of wave energy.

In England the opportunities to do IRPs within science qualifications began to diminish from September 2015, with the introduction of new regulations for assessing A level science practical work: these effectively mean the end of the projects that used to be an integral part of the Salters A level courses in Chemistry, Physics and Biology. A promising development has been the growth of the EPQ, but so far only a small minority of these projects involve practical science[3], and the standardised assessment scheme for EPQs can limit their scope for IRPs.

2 WJEC. *Welsh Baccalaureate From 2015*. wjec.co.uk/qualifications/welsh-baccalaureate/welsh-bacc-from-2015/

3 Research by the Wellcome Trust in 2014 and 2015 indicated that, collectively, less than 10 per cent of EPQs that focus on biology, chemistry or physics are based on a practical investigation.

2. The impact of Independent Research Projects on students

Understanding impact was a critical part of the Review. It seems intuitively likely that IRPs will have a positive impact on students, and indeed the Review found that "almost all publications report benefits to participation in IRPs". However, much of the evidence needs to be treated cautiously because impact studies are often undertaken by people who have been involved in the IRPs or who are already positively disposed towards them. Therefore, overall, the quality of evidence on the impact of IRPs can, at best, be described as "fair to good". In order to advocate for IRPs we need to have better and more independent evidence of impact.

Even so, the Review judges that there is evidence for a range of benefits to IRPs:

- **gains in students' learning**
- **improvements in students' attitudes to science**
- **increased numbers of students considering careers in science**
- **particular benefits for students from traditionally under-represented backgrounds**
- **making students more aware of a broader range of careers in STEM**
- **helping students develop a range of higher-level qualities including independence, self-esteem, tenacity and a sense of scientific identity.**

These are the kind of findings that will be persuasive to headteachers and policymakers.

Furthermore, since the Review was conducted, the British Science Association published the results of a robust independent study of students who have achieved CREST Silver Awards. CREST awards are given to students who carry out project work in science, and the study found that Silver CREST award students[4]:

- achieved half a grade higher on their best science GCSE than a statistically matched control group – this impact was greater with those from socially disadvantaged backgrounds (as assessed by eligibility for Free School Meals), whose best science GCSE was two-thirds of a grade higher than those of a matched control group
- are 21 per cent more likely to take a science, technology, engineering or maths (STEM) AS level (82 per cent took a STEM AS level compared to 68 per cent of a statistically matched control group) – again, this impact was greater with those eligible for Free School Meals, who were 38 per cent more likely to take a STEM subject at AS level than their matched control group.

It is important to note that this study could only describe a correlation between participation in CREST and GCSE grades; it could not control for unobserved differences, such as motivation and enthusiasm for science. Nonetheless, the CREST award study is consistent with what supporters of IRPs have always believed and with what the Review gives us evidence for: that IRPs inspire students so they achieve higher grades and are motivated to continue with science.

The Review also found benefits for teachers as a result of offering IRPs to their students. Teachers report professional satisfaction, improved teaching skills, improved relationships with their students, and increased professional networks with external partners in universities and industry. People entering teaching with postgraduate research experience are particularly well placed to support IRPs and to benefit from doing so.

4 Stock Jones R, Annable T, Billingham Z, MacDonald C. Quantifying CREST: What impact does the Silver CREST Award have on science score and STEM subject selection? A Pro Bono Economics research report for the British Science Association; 2016. www.britishscienceassociation.org/crestsilver-report

3. What are the barriers to adopting IRPs in schools and colleges?

With benefits like those described above, you might expect every school and college to embrace IRPs, but they remain very much a minority occupation. The Review gives some insights to why this is.

IRPs are seen as challenging for teachers, students and external partners. The stringent accountability and assessment regime within which many schools operate, certainly in England, heightens these challenges, putting pressure on any activity that is not perceived to pay off in external examinations.

For teachers, the challenges are around:

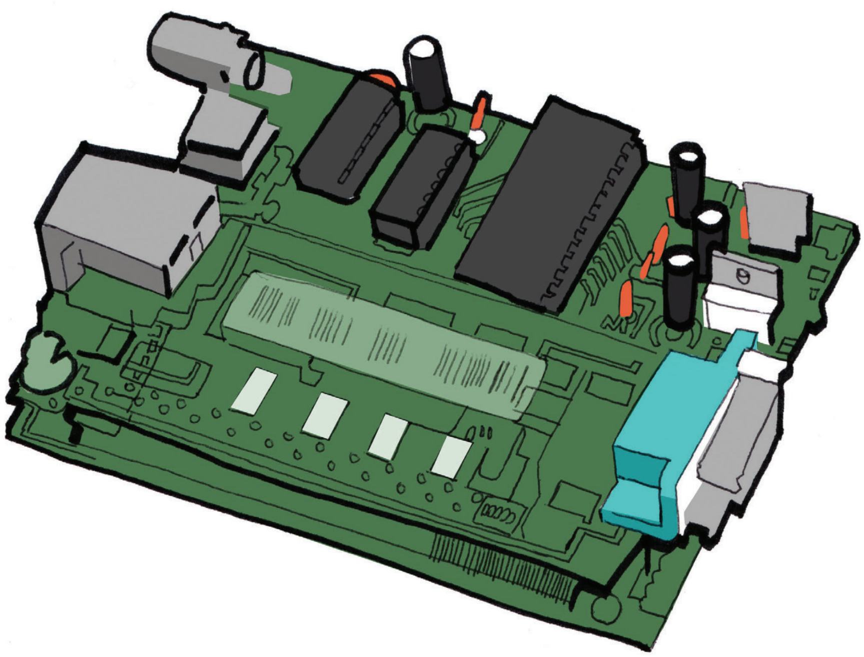
- the time required to prepare and to support students
- the expertise needed – often IRPs take teachers outside their zone of expertise
- the resources needed – equipment, lab space and technician support; IRPs can tie up space and equipment for long periods
- the time and effort needed to identify and build relationships with partners.

Of course, several of these barriers are not unique to IRPs.

Students may also see IRPs as too challenging, particularly because of the workload and the need to balance IRPs against other demands on their time.

The Review notes that an important factor contributing to the success of IRPs is organisational culture. If a school or college culture embraces and celebrates IRPs, it is more likely that the structures and systems of support will be there to drive them forward. Such structures might include guaranteed time, a science club or an external structure such as a science competition or fair. But if the school sees IRPs as a distraction from the serious business of exams, then IRPs are unlikely ever to thrive.

If IRPs had a more tangible payoff in terms of short-term benefits like exam grades, students and teachers might be motivated to overcome these challenges. But as we have noted, in England the trend is to remove IRPs from assessed schemes such as A levels. There are concerns about the assessment of IRPs, which essentially has to be performed by teachers, but the Review notes that there is little available evidence on the validity and reliability of this assessment. We return to this theme in section 4.



4. What more might be done to encourage IRPs?

Partners

The Wellcome Trust is not alone in advocating for IRPs in science. In 2014 and 2015, Wellcome convened an informal discussion group of interested parties, including:

- the Royal Society, which has long supported science IRPs through its Partnership Grants scheme[5]
- other learned societies including the Royal Society of Chemistry, the Institute of Physics and the Royal Society of Biology
- the British Science Association, which runs the CREST Awards scheme
- the Nuffield Foundation, which organises the Nuffield Research Placements scheme
- Research Councils UK, which supports partnerships between universities and schools
- the newly formed Institute for Research in Schools, which promotes and supports IRPs
- representatives from Awarding Organisations.

We hope that the community of interested parties recognise the value of sharing insights and reflections on IRPs and will continue to collaborate to help shape the future of IRPs in school.

Advocacy

We have drawn together independent evidence for the impact of IRPs. Until now, advocates have worked from anecdotes and intuition, but now they can and should become more evidence-based. What aspects of the evidence are likely to be most convincing to headteachers and policymakers?

Impact on attainment (especially exam grades) is always going to impress headteachers, but there is more. Evidence that IRPs are associated with even higher grades among disadvantaged students, such as we see from the CREST evaluation, is especially relevant. Further robust evidence that IRPs support equality and diversity goals (for example, if IRPs improve girls' uptake of the physical sciences) would also be persuasive. This may be an area for further research.

The Review shows that IRPs in science can widen students' awareness of careers in STEM and of the range of STEM specialisms. This is in line with the Gatsby report on Good Career Guidance[6], which includes among its benchmarks "Encounters with employers" and "Encounters with further and higher education". There may be a case for involving the Careers and Enterprise Company[7] in this work, because its network of Enterprise Advisers can help schools to form the external partnerships that are so important to successful IRPs. There is an important role for the National STEM Learning Centre.

5 Royal Society Partnership Grants of up to £3,000 are available to schools to enable students aged 5–18 to carry out science, technology, engineering or mathematics (STEM) projects.

6 Holman J. Good Career Guidance. Gatsby Charitable Foundation; 2014. gatsby.org.uk/GoodCareerGuidance

7 The Careers and Enterprise Company, established with government funding in 2015, brokers contacts between schools and employers through a network of Enterprise Advisers. careersandenterprise.co.uk

A place in the curriculum

What would be truly transformative is for IRPs to become a core element of the curriculum for every student by the time they leave compulsory education. There are plenty of precedents for this. The Dutch example of the *profielwerkstuk* shows what is possible in a country that is similar culturally and economically to the UK. The 'Transition Year' in the Irish Republic (an optional year in which students can undertake projects and work experience) offers great scope for IRPs. The International Baccalaureate has long included an extended essay: an independent, self-directed piece of research, culminating in a 4,000-word essay.

Wales and Scotland show what is possible in other UK nations than England. The new Welsh Baccalaureate (first teaching in 2015) requires students to undertake four "skills challenges", alongside GCSEs in English or Welsh language and mathematics, plus at least two Level 3 qualifications, such as A levels. Half of the skills challenge certificate comprises an individual project, which is similar in scope to an EPQ. Similarly, the Scottish Baccalaureate in Science requires the Interdisciplinary Project, "which must involve a science based investigation or practical assignment". Although none of these examples are exclusive to science (students may choose any subject they wish for their project), by making the project a compulsory part of the curriculum, these examples greatly increase the likelihood that students will embark on a science IRP.

A broader post-16 curriculum in England has been debated for longer than most of us can remember, and recently it was called for by the Royal Society in its 2014 *Vision for Science and Mathematics Education*[8]. Similarly, Sir Roy Anderson's 2014 report *Making Education Work*[9] calls for a broad curriculum which includes a compulsory individual project: "Project work evidenced by the Extended Project and other qualifications should become a key requirement for university entrance." Universities have already acknowledged the value of EPQs, but it would be a powerful way to incentivise IRPs if universities gave them additional credit.

Assessment of IRPs

If science IRPs are to become mainstream rather than peripheral, we need a robust way to assess them so that the gatekeepers to further and higher education can reliably judge their worth. Ofqual's approach to the assessment of practical science in the new A levels and GCSEs has shown an aversion to trusting any form of assessment that relies on teachers, yet it may be that there is no other realistic way to assess practical IRPs on a large scale. While this may be unproblematic in the Netherlands and many other countries, it is problematic within the English system with its competing exam boards and heavy emphasis on high-stakes external exams.

There will always be a place for IRPs that are unassessed, or assessed informally, for example via competitions. But it would be a shame if the demand for IRPs were to grow, but then to founder on intransigent assessment. It is a matter of some urgency to research assessment systems for IRPs (for example, within the EPQ) which will win the confidence of the qualifications system and the public.

8 Vision for Science and Mathematics Education. Royal Society; 2014. royalsociety.org/topics-policy/projects/vision/
9 Anderson R. Making Education Work: A report from an independent Advisory Group chaired by Professor Sir Roy Anderson. Pearson; 2014. uk.pearson.com/about-us/news-and-policy/reports-and-campaigns/making-education-work.html

Sustainability and funding

Successful IRP schemes like the Royal Society Partnership Grants, CREST Awards, Nuffield Research Placements and Authentic Biology are dependent on external funding. If IRPs are to become mainstream, a sustainable way of supporting them needs to be found.

The Institute for Research in Schools has promising prospects for leadership in this field, but it would need to widen the scope of its interest and activity beyond high-intensity schemes with low numbers like Authentic Biology – excellent though they are – to explore and support mass-participation schemes, for example through EPQs.

The EPQ suggests a model for sustainability as schools that offer EPQs essentially fund their own project work as part of students' qualifications. Additional external support, such as the Royal Society Partnership Grant scheme, could fund schools that want to take projects further.

A critical element of a successful IRP is often the partnership with academia or industry, but the Review highlights the need to find partners as one of the barriers. Clearing-house schemes, like those provided by STEMNET and Tomorrow's Engineers, can broker partnerships by putting schools and colleges in touch with partners. In the Netherlands, some universities have hotlines for students needing help with their *profielwerkstuk*.

Research

Unsurprisingly, the Review points to areas where more research would be useful. We think the following are of interest:

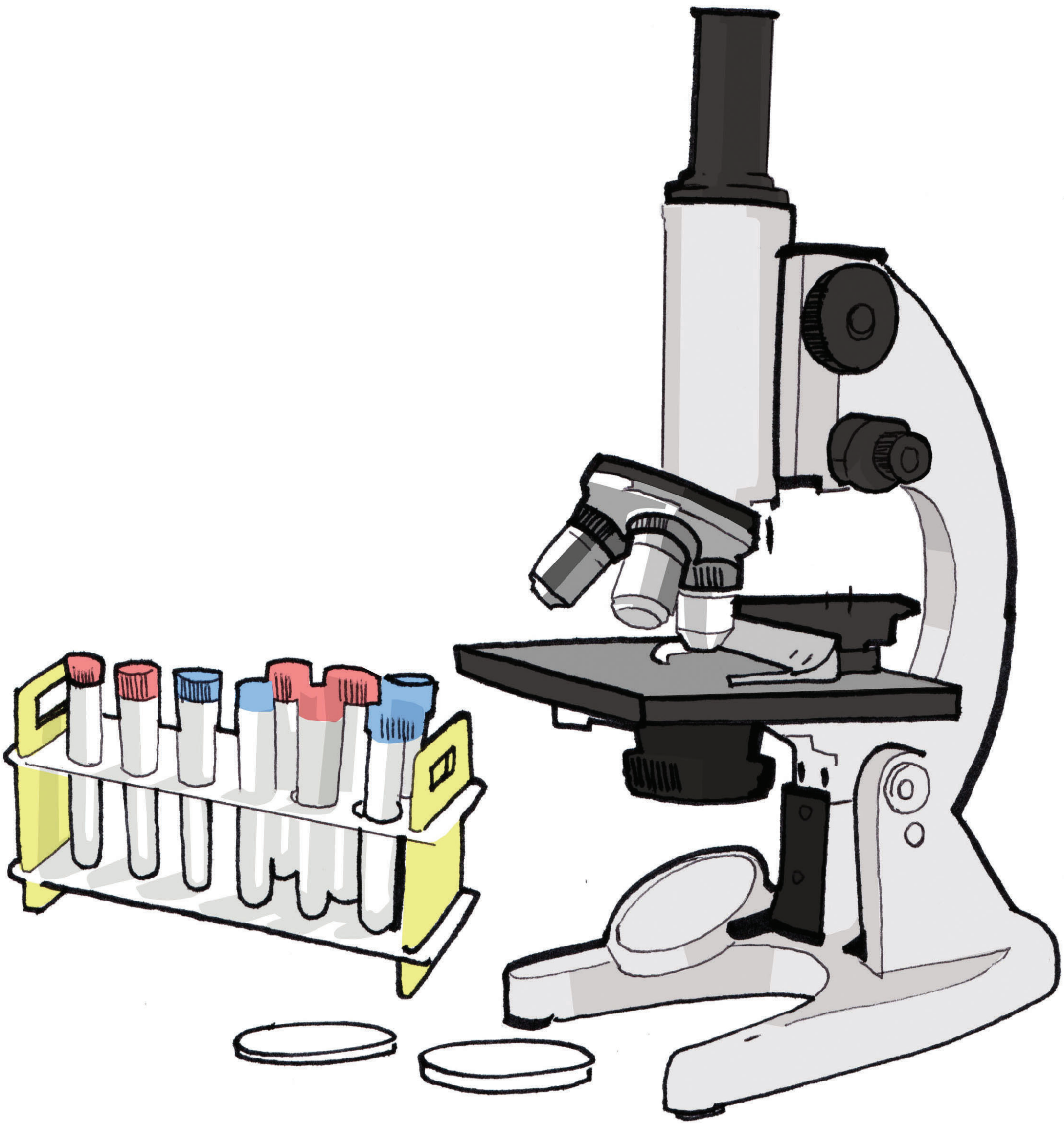
- The possible long-term benefits (or any disadvantages) for students who have undertaken science IRPs.
- More robust research designs to measure the impact of IRPs, with less reliance on self-report data, and greater use of control and experimental groups. These could be applied to well-established schemes such as Authentic Biology and Nuffield Research Placements, perhaps adapting the methodology used for the CREST evaluation described above.
- Assessment systems for IRPs which will retain the confidence of the public and the qualifications system.
- Better data on the scope of IRPs, particularly data on IRPs that exist outside the known universe of national schemes.
- Better understanding of the differing impact of IRPs on different groups of pupils, including by gender or social background.
- Better understanding of how some schools and colleges facilitate mass participation in IRPs.
- Analysis of the cost (time and resource) of requiring all science students to do an IRP in England. This could be linked to an analysis of the costs of different types of project.
- Comparison with other subjects where projects are more common.

Given the wealth of experience in other countries, we are interested in the Review's suggestion of an international symposium on IRP work.

5. Conclusion

The Rapid Evidence Review has strengthened our conviction that independent research projects in science can unleash the potential of young people more effectively than traditional teaching alone. In the words of one of the Review's key informants: "This is as good as it gets in science education."

But the Review has also shown us how severe the barriers to IRPs in ordinary schools can be, and it has shown us some areas where we need to collect more robust evidence to understand the impact of IRPs and build partnerships for advocacy.



Appendix 1. The Wellcome Trust's existing work to support independent research projects

IRP schemes

Authentic Biology was pioneered by Dr Dave Colthurst at Simon Langton Grammar School for Boys in Kent. The scheme's approach is to pair a school with its local university, drawing upon their skills and resources to facilitate authentic, research-grade student projects. Now in its fifth year, Authentic Biology has grown to include an additional six schools across England. If carried out appropriately, projects may lead to an EPQ. It's the gold standard and can produce some superb results, with research done by sixth-formers akin to that expected from undergraduate and even postgraduate students. Examples of projects initiated and undertaken by students include:

- Post-translational modification of human Myelin Basic Protein in yeast
- The effects of ethanol and methanol upon the fruit fly – *Drosophila melanogaster*
- What is the effect of Imidacloprid on *C. elegans*' sensorimotor coordination?

Nuffield Research Placements[10] are another example of school and college students working with universities and industry. Developed by the Nuffield Foundation, the Placements have been running for over 20 years and during this time over 15,000 students have participated. Since 2001, support from Wellcome has enabled roughly 100 students each year to undertake a four-to-six-week biomedical research placement over their summer holidays. Students rarely devise their own projects, but they work alongside practising researchers, making a real contribution to their work, and gaining valuable insights into the real world of research. Currently, Nuffield is seeking to extend its reach to engage more students from disadvantaged backgrounds.

EPQs, while not a scheme like Authentic Biology or the Nuffield Research Placements, are very promising because of their popularity and the fact that they offer UCAS points. Wellcome's support for EPQs is through the development of student resources, as described below.

Resources to support IRPs

We have created two key resources that support IRPs and are transferable across, for example, EPQs, the Welsh Baccalaureate Individual Project and the Scottish Baccalaureate Interdisciplinary Project.

The first is a magazine guide for students that helps them to identify a practical research project that they could carry out. We know that for EPQs, in particular, students can struggle to identify their own research question that can be addressed through a practical investigation. By encouraging them to think about their own interests and steering them through the process, we hope to increase the number of projects and investigations based upon practical experiments.

A key facet of research is ethics and we are conscious that learners are less likely to have encountered ethical considerations when undertaking routine practical lessons. Accordingly, we have also developed both an ethics guidance sheet for students and a teaching module, which we hope will mitigate poor/unethical research practice.

Our aim is that by using these resources in tandem, teachers and students are able to identify and undertake meaningful, high-quality research projects.

10 Nuffield Research Placements are supported by the Nuffield Foundation with contributions from the Wellcome Trust, Research Councils UK, the Royal Society of Chemistry and the Microbiology Society.

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