**What enables successful open-ended practical investigative work in the sciences post-16?**

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**Abstract**

The Gatsby Good Practical Science report (Gatsby, 2017) identified opportunities to carry out open-ended investigative projects as one of ten benchmarks for good practical science. However, there is currently no requirement for post-16 students in England to have access to such opportunities as this is not required by A level specifications (the most common post-16 qualification in England). Nevertheless, some teachers incorporate open-ended investigative work nature into post-16 teaching. Drawing on in-depth semi-structured interviews with twelve teachers, enablers of and barriers to open-ended investigation are identified, and the ways in which several teachers have successfully implemented such work are demonstrated through vignettes. Ways that teachers can use and value open-ended project work within current A Level specifications are presented

**Keywords**

investigation, inquiry, open-ended, practical work, A Level

**Introduction**

Open-ended projects have been identified as a benchmark for good practical science (Gatsby, 2017, p.13), and are associated with a number of benefits for young people, including gains in understanding of scientific ideas; development of a range of skills; and improved attitudes towards science (see for example Bennett et al., 2016 for a review of evidence). However, recent changes to the Advanced Level (A Level) specifications in England from 2015 means that there is no longer a requirement for most post-16 students in England to carry out open-ended investigative work. Instead, the requirement is for students to complete at least 12 set practicals, which are both indirectly assessed by examination (worth at least 15%) and for which students are awarded a ‘practical endorsement’ separate to their A level grade. As a result, open-ended investigative work at A level is now optional. A recent study found few teachers provide opportunities for open-ended investigative work for students (Cramman et al., 2019).

**What are open-ended investigations?**

Investigations are activities in which students design an experiment to test a given question, carry it out and interpret the results, all within a fixed time period (Gatsby, 2017, p.13). In such work, students cannot immediately see an answer or recall a routine method for finding it (Gott and Duggan, 1995, p.14). Hence, whilst an answer and appropriate methods might be known to science, they are not yet known to the student.

Investigations can be open to varying degrees. Buck, Bretz and Towns (2008, p.54) identify six characteristics of inquiry-based work. The six characteristics are:

* *problem/question*
* *theory/background*
* *procedures/design*
* *analysis of results*
* *communication of results*
* *conclusions*

In this study, projects are considered to be open-ended where at least one of the above characteristics is not provided, because this allows students to make decisions about their work where there is more than one possible response.

In their review of inquiry-based science instruction, Minner et al. (2010) described as including science content, student engagement with the content, and student responsibility for learning, student active thinking, or student motivation within at least one component of instruction (stated to be question, design, data, conclusion, or communication). They found a trend towards inquiry-based instruction reported in research literature, although the majority of these studies were carried out in the USA. In terms of outcomes, they found that just over half of the studies included in their review reported positive impacts of inquiry on student content learning., The outcomes of interest were (i) student understanding of science concepts, facts, and principles or theories; and (ii) student retention (a minimum of 2 weeks after treatment) of these science concepts, facts, and principles or theories. These outcomes might not correspond to teachers’ intended learning outcomes for such work.

The purpose of this article is to share findings from a recent series of interviews conducted to answer the question:

*What enables successful practical, open-ended and extended investigative project work in schools or colleges, and what barriers exist?*

The findings are likely to be of interest to teachers and department leads who would like to create space for this work, whilst managing the time available to teach post-16 sciences.

**Methods**

Following approval granted by the relevant Ethics Committee, voluntary informed consent was obtained from participating teachers. Open invitations to participate were circulated *via* personal and professional networks.

A questionnaire was used to characterize work carried out in school by teachers and to identify intended learning outcomes. Only teachers describing projects that were structured, guided, open or authentic (n=15) were invited to participate in an in-depth semi-structured interview about their experiences of investigation at post-16. Interview transcripts were analysed to identify enablers and barriers to open-ended investigative work, and for ways in which teachers negotiated any barriers. Vignettes provided by four of the interviewed teachers represent their experiences of open-ended investigative work at A Level.

As this is a qualitative study, we have not provided numbers of responses to different questions. We wish to avoid claims of generalizability, and instead draw attention to describing the different ways that teachers have approached open-ended investigation that may be relatable to other teachers in different contexts.

**Participants**

Twelve teachers of biology (n=6), chemistry (n=4) and physics (n=2) were interviewed (four female; eight male). All teachers worked in the state sector (in different schools and post-16 colleges) and had been teaching for longer than five years. All institutions had been judged by the inspectorate Ofsted[[1]](#footnote-1) as ‘good’ or ‘outstanding’, with the majority (n=7) rated ‘outstanding’. Teachers worked in schools and colleges in England (Dorset, Kent, London, Norfolk and Yorkshire) in a range of neighbourhood types, from rural town fringes to major urban conurbations. The majority (n=10) were located in the least deprived neighbourhoods in England[[2]](#footnote-2) (i.e. above the fifth decile) and only one was located in a neighbourhood in the most deprived decile.

**Results**

***Why offer open-ended investigations to post-16 students?***

The teachers in this study reported providing open-ended investigative opportunities for post-16 students for different reasons. These included:

1. Allowing students to pursue their own scientific interests.
2. Meeting qualification requirements, for example the Common Practical Assessment Criteria (CPAC) associated with the A level.
3. For broader educational value, for example, to make decisions about how to carry out an investigation and to develop persistence, resilience.

There was considerable diversity of practice reported by teachers in this study. Fuller details of the types of investigation can be found at [link identifying; to be inserted post-acceptance]. Although the ways in which the teachers offered open-ended investigative projects varied, six key learning outcomes were identified from the initial questionnaire. These are presented in Table 1, based on a synthesis of the questionnaire responses. The interviews revealed that these intended learning outcomes shaped how teachers structured projects for students.

Table 1: Learning outcomes for open-ended investigative work post-16

|  |  |
| --- | --- |
| **Key learning outcome** | **Description**  |
| State of the field | This idea relates to learning about how knowledge is created in the discipline, including how to search and review literature, and how students understand their work in relation to the state of the field. For example:“I will find a research paper, to show they are on the right path, then ask them to read the method and see if it is something we can do….key word search…. scaffolding as required.” Biology specialist. |
| Research design | This refers to learning how to make decisions about the methods used to answer a research question, including about experimental design, methods of data collection and analysis, safety and ethics. For example:“Formulating a testable hypothesis. The ability to think about how variables might be controlled.” Physics specialist |
| Iteration  | This refers to learning how to handle the repetitive and recursive (rather than linear) process linking data collection and analysis during which students might notice unexpected results, test procedures or make amendments to their methods. For example:“Simply - improving technique with using equipment, making choices and recording \*everything\* in their lab book.” Chemistry specialist. |
| Data handling | This includes learning how to make decisions about data collection and evaluation, including how decisions are made about the suitability, adequacy analysis, interpretation and presentation. For example:“I hope students will appreciate the challenges and rewards of carrying out their own independent research which might involve troubleshooting, unexpected results, results that open new areas to investigate.” Biology specialist |
| ‘Real’ science | This refers to the sense that teachers want students to find out about ‘real’ science, and do work similar to the things professional scientists do. For example:“Learning how to present a conference style poster.” Physics specialist.  |

The intended learning outcomes identified by teachers in this study correspond to Minner et al.’s (2010) components of instruction (question, design, data, conclusion and communication), although there was less emphasis on conclusion, and communication was included in the idea relating to ‘real’ science. These intended learning outcomes are likely to be useful in developing lesson plans and resources to support the teaching and assessment of open-ended investigation at post-16.

***Ways to incorporate open-ended investigations into the post-16 curriculum***

Boxes 1-4 present vignettes from teachers who teach a science at A Level and who incorporate open-ended practical investigation into their teaching. The vignettes represent different approaches and priorities for open-ended investigation, with varying degrees of student independence.

For example, Aba Adebanjo (Box 1) takes a long-term structured scaffolded approach, moving from confirmation-type practical work in the first year of an A level course to open-ended investigation in the second year. For example, in the first year, she might teach how to do titrations, and in the second year, students use the technique to answer a question that requires them to determine the concentration of an analyte.

**Box 1: Aba Adebanjo, Westminster City School**

“I have been developing scaffolding techniques to assist students to devise methods in chemistry practicals which will allow students to really think about how and why they are doing experiments.

I like to emphasise with students that they will be given a problem to solve as future scientists and chemists as opposed to a list of instructions to follow. So firstly when students are introduced to a new experiment we go through the theory to understand what is going on. We discuss what the purpose of each piece of equipment and link it to when we might use each for a particular step of a method. Students will follow the method and complete the experiment.

The next time we do an experiment it would be a case that they are given just the equipment needed for the experiment and they will then need to devise a method to meet the aim after a group discussion.

By the time we get to 2nd year of the A Level course, students would be given an aim and the equipment (some included that would not necessarily be needed to complete the experiment) and students will have to devise their own experiment to meet the objective. The process being that each time they complete an experiment they are given less information so it will require more problem-solving from themselves which better prepares them for work in industry or research.”

Simon Moore (Box 2) describes how he introduces his students to open-ended investigation through a study of woodlice. Simon takes advantage of his school calendar to offer projects in the summer term, and uses the work they do to contribute to the Common Practical Assessment Criteria (CPAC) for A level.

**Box 2: Simon Moore, Wymondham High Academy**

“Woodlice are supposed to change direction in a predictable way. After a ‘forced’ turn they should make their next turn in the opposite direction. But woodlice are unpredictable. There are many species, with variation in how they can ‘forget’ which way they are supposed to go, and many persist in doubling back on themselves thwarting the very best attempts at obtaining valid data.

Investigating woodlouse turning behaviour is the “base” practical for my A Level students who can then develop their own unique research question and method for an extended investigation. Health and safety concerns, technician support, and resources requirements are all minimal[[3]](#footnote-3).

Running an extended investigation soaks up curriculum time. I usually allocate 15 hours of lesson time but this is mitigated by running the project in the late summer term, in parallel with year 12 exam preparation and the inevitable absences due to university visits, field trips and festivals.

Specifications have come and gone and I have retained this investigation even when it has had only cursory links to the relevant practical requirements. The switch to the practical endorsement has secured the woodlouse a place in our current course, with all teachers and classes making of the most of the good coverage of the CPAC.”

Two other approaches to open-ended investigation are presented in boxes 3 and 4.

***Enablers of open-ended investigative projects in the curriculum***

From interviews with teachers, we were able to identify ways in which they were supported to offer open-ended investigative work post-16. These related to teacher experience, the science department, senior leadership in schools and external support.

* ***Experience***

Prior experience was an important enabler of open-ended investigative work. Some teachers drew on their own undergraduate, postgraduate, academic or industrial research experience. Others described using their experience of teaching open-ended investigative work through previous versions of specifications, e.g. Salters’ A Level Chemistry. See Box 3 for how Simon Poliakoff has drawn on his experiences of other curricula to create opportunities for open-ended investigation for his current A Level students.

**Box 3: Simon Poliakoff, Dame Alice Owen’s School**

“During the first ten years of my teaching career the A Level physics students had to complete open-ended investigations as part of the then specification which my school followed.  The students found this a real challenge at the time but over the years students who returned to visit often said how well it had prepared them for longer practicals and projects at university.   We decided as a department to try and recreate what we liked and the students found most beneficial.

we produced a list of open-ended investigations that students can choose. They spend five hours of practical work on their project in the summer term of year 12, working either individually or as a pair.  These projects teach topics they have studied, as well as some topics they will learn in Year 13.   Some projects have simple practical set up and complicated background theory, whilst others have simple theory but more complicated practical set up.  The students are provided with some background reading and a starting point. They must produce an equipment list and plan which can be modified as they go along.  Rather than producing a written report which the students found onerous (when it was coursework), the students have to produce a conference-style poster which they can work on collaboratively.

An example of an investigation with a simple practical set up is the simple harmonic motion of a ruler balanced on a horizontal cylinder.  You can change the length of ruler, thickness of ruler, material of the ruler, or diameter of the cylinder.  A more challenging practical set up is investigating the induced emf of a magnet dropped through a coil which requires setting up a sampling oscilloscope to trigger and this also involves theory which they have touched on at GCSE[[4]](#footnote-4) but haven’t yet studied at A Level.

Some of the key benefits to the students are being forced to make significant decisions about what variables to investigate, learning to solve problems with practical equipment, getting more experience of using equipment such as oscilloscopes as well as having the time to refine and improve a method without the stress of having to complete everything in one hour.

* ***The science department***

Teachers in the study reported that Heads of Science enabled open-ended investigative work by timetabling open-ended investigation for all or part of the year, allocating a dedicated room for this work, and allocating staff to this work (recognised in workload models). Teachers in the study also recognised that they had freedom to decide what and how they teach.

The teachers also recognised the importance of skilled and supportive technicians who could dedicate time to find, test and refine procedures, maintain equipment and consumables, safeguard living organisms, train students in procedures, and carry out risk assessments.

* ***School senior leadership***

School leaders enabled project work by selecting post-16 curricula that value open-ended investigative work and allocating staff time and space to this. Where this was at A Level, leaders were supportive of supplementary qualifications and awards such as the EPQ (Extended Project Qualification[[5]](#footnote-5)) and CREST (Creativity in Science and Technology[[6]](#footnote-6)) Awards. These awards allow students to gain recognition for their own investigative work.

The teachers who taught only within specialism reported that they believed this helped them to offer open-ended investigation because their time was not used to master their non-specialist subjects.

School senior leadership also supported open-ended investigative work by allowing departments to decide when to begin teaching ‘year 13 content’. Investigative project work was also enabled when institutional libraries were well-resourced and staffed by librarians who could help with literature search strategies. In Box 4, Martin and Tanya describe their experiences of making open-ended investigation ‘count’ by valuing it in the school timetable, particularly for students not taking four A Levels. The CREST Award is assessed by the British Science Association, against published assessment criteria.

**Box 4: Martin Hampshire and Tanya Hunt, Bournemouth School**

 “In the sixth form at Bournmouth College, students have the option of studying four A-levels or three A-levels and, in year 12 only, one of CREST Gold, Pre-U[[7]](#footnote-7) or Additional Maths.

Open-ended investigations are supported through the CREST Gold option. This requires 70 logged hours of work, which can be counted as part of a student’s contact time in terms of school funding formulae. Logged capitation spend specific to the CREST course has been £10 per student for the equipment and £20 per student for the assessment by CREST. Some other costs have either been borne by the students themselves or have used generic science department resources. There is a small science lab in the department and this has been used as a base for the CREST groups, but it is also used for A Level classes when needed. Students have five fifty-minute lessons a fortnight and write up their findings as a report.

Initial lessons were spent identifying students’ interests and helping them identify a question to be investigated. There were no limits to choices other than we had to be able to investigate it using standard apparatus (some examples from this year - Best type of flour for making bread / Best spike length for sprinting shoes / A device to prevent smudging for left-handed writers / Best material for skateboard shoes / The best method to transport people with spinal injuries / Comparing the effects of caffeine and sleep on young adults’ memory).

The next set of lessons covered research methods and referencing (with the help of a librarian), how to structure an investigation and the key scientific process terminology, basic spreadsheet skills for recording and analysing results and how to contact external companies and organisations in order to gather further information. These are skills relevant to any student. For most of the year the students have worked on their own, with each lesson starting with a quick check for any issues. Students have had a fortnightly 15-minute mentoring meeting with the class teacher. Access to computer rooms for the report writing has been achieved by sharing the spare spaces from other classes. There is no specific deadline so each student’s work has been submitted as it has been completed. So far all have passed and the comments from assessors show that the expected level of performance is realistic for a typical A Level student with limited access to resources but who is prepared to put the effort and hours into their work.

External ‘mentors’ are preferred by CREST for the Gold level. We managed to find mentors for half the students *via* the STEM ambassador website[[8]](#footnote-8). The best were those with a wider interest in science than their own specialism as they were able to quiz/talk to the students about the scientific process.

This year there are 18 students split into two groups. Next year there will be up to 30 students split between the two groups as the option is popular. Feedback from the students has confirmed that the ability to choose a project of interest to them has been a key element of their commitment to and enjoyment of the course; every single student said that they would choose to do the CREST Gold course again.

In addition we have entered some of the CREST Gold students’ work for the local Big Bang Science Fair Competitions[[9]](#footnote-9). This has added a whole extra dimension to the course which the students enjoyed. One of our cohort will now be at the National Finals at the National Exhibition Centre in March 2020.”

* ***External support***

Open-ended investigations were also enabled with support from the scientific community. Support included responses to teachers’ questions, provision of professional development opportunities, mentoring (see Box 4), hosting students or staff, or providing analytical support. Grant funding (including teacher buy-out) also enabled teachers to develop opportunities for investigative work.

The assessment policy context was also identified as enabling open-ended investigative work. Teachers reported concern that previous iterations of the GCSE had resulted in a formulaic approach to investigation. That said, the absence of investigative work in specifications was also seen as problematic – although some schools were following alternative programmes that require investigation (BTEC Nationals[[10]](#footnote-10); the IB[[11]](#footnote-11) Diploma Programme), were offering alternative award schemes (CREST), or were using open- ended investigations to demonstrate that a student had met the CPAC. Some teachers felt that the CPAC offered the opportunity for creativity in the assessment of practical work and multiple opportunities allowed teachers to plan for progression, moving from very structured practical work to open-ended investigative work, and several teachers reported that this was more supportive of open-ended investigation than the prescriptive approach that existed prior to the CPAC.

***Meeting the challenges associated with open-ended investigative projects***

Even in schools where there was an established culture of open-ended investigative project work post-16, teachers identified challenges to the continuation of this work. Table 2 (policy), Table 3 (student experience) and Table 4 (school infrastructure) present the reported challenges and how teachers in this study have successfully negotiated each challenge.

**Table 2: Challenges relating to** **the external policy context**

|  |  |
| --- | --- |
| **Challenge/Barrier** | **Teachers’ responses** |
| ***Curriculum and assessment*** Open-ended investigations are not perceived to be valued in the examination of A Levels.  | * Move to a curriculum that values open-ended investigative work (e.g. the IB or BTEC).
* Timetable project lessons leading to a recognised award (e.g. CREST).
* Use investigations as evidence for students’ practical endorsement.
 |
| ***Health and safety*** Demand is greater than a single teacher can cope with for some projects where procedures are hazardous, and projects which give students free choice over topic and design require piloting and individual risk assessments, which represents an additional workload.  | * Ask technicians or initial teacher education students to search, test and refine procedures.
* Trial some steps as an extra-curricular activity with a few students or with a technician, possibly in the school holidays.
* Constrain choice by topic or technique.
* Ask CLEAPSS[[12]](#footnote-12) and equipment manufacturers for support.
* Enable more experienced colleagues to support those with less experience.
 |
| ***Funding for staff time*** Departmental and school timetables and grant funding rarely acknowledge or recognise teacher and technician time. | * Work voluntarily beyond timetabled hours.
* Apply for external funding that pays for teacher time.
* Timetable project time as any other timetabled subject and link to CREST award, the EPQ and/or UCAS applications.
* Relieve teachers who run open-ended investigations from other duties.
 |

**Table 3: Challenges relating to the student experience**

|  |  |
| --- | --- |
| **Challenge/Barrier** | **Teachers’ responses** |
| ***Distraction***Open-ended investigation can be seen as a distraction from meeting exam specification requirements.  | * Position investigations as a means by which students can understand and apply specification content knowledge.
* Use projects to demonstrate that students have met the CPAC.
* Use data sets to compare cohorts doing project work with those who are not to monitor impact on attainment.
 |
| ***Demand*** It can be difficult and/or demoralising for students to cope with and interpret unexpected results. Mathematical and statistical demand can be greater than had been taught. Students sometimes struggle to understand scientific methods. | * Teachers shared their own experience of investigations in industry or academia.
* Teachers demonstrated that they were learning too.
* Explain that dealing with the unknown and unexpected is integral to the practice of ‘real’ science.
* Build maths and statistics practice questions into the course from the start.
* Teach and ask students to apply statistics in new science contexts through open-ended projects.
* Use open-ended investigation to teach about ‘real’ science, research design, data handling and analysis.
* Encourage peer support by offering after-school support for students in different year groups.
 |
| ***Motivation***Student motivation can be low at the end of year 12 in summer. Some students take an instrumental approach to learning and are reluctant to go beyond the specification. | * Offer an open-ended project where students have the freedom to investigate something of interest to them.
* Use as evidence for students’ practical endorsement.
* Model enthusiasm, love of learning and interest in finding out about the world or problem-solving.
 |
| ***Access***Not all students can access extracurricular project work.   | * Create opportunities for project work in class time, particularly at the end of year 12 or through timetabled CREST awards.
 |

Table 4: **Challenges relating to infrastructure**

|  |  |
| --- | --- |
| **Challenge/Barrier** | **Teachers’ responses** |
| ***Access***Research articles are often inaccessible to students e.g. recent papers are behind paywalls. Access to external partners. | * Collaborate with academics who can provide access.
* Subscribe to journals such as Chemistry Review.
* Teachers in cities were able to draw on STEM Ambassadors and university scientists.
* Academics were often open to email contact.
 |
| ***Resource*** Equipment available in school constrains students’ approaches.  | * Teachers sought internal (e.g. PTA) and external (e.g. Royal Society) funding.
* Liaise with a university and negotiate access to equipment.
* Ask for ex-display models from manufacturers.
 |
| ***Space*** Many schools and colleges no longer have a spare laboratory for project work.  | * Designate a laboratory as a ‘project lab’ for part of the year and protect this in the timetable.
* Redeploy small classrooms no longer suitable for larger class sizes.
 |
| ***Time-boundedness*** Extended investigative work does not fit well with school timetables.  | * Request additional timetabling in the summer term when students are often out of class doing exams, on trips, or conducting fieldwork.
* Encourage ‘kitchen’ or home science, with students bringing data or samples to school.
 |
| ***Demand***Open-ended projects generate many different questions for the teacher; specialist equipment cannot be used by large numbers at once; consumables are expensive for large cohorts of students.  | * Offer an optional project or club at the start, moving into timetabled time as experience is gained.
* Involve colleagues of the same subject to co-plan and share supervision duties.
* Use a weekly slot when students are free.
* Enlist the support of technicians, visiting students, ITT students and NQTs to support projects.
* Constrain choice - identify known procedures that can be adapted to new contexts.
* Allow pair or group work.
* Rotate project work with other special projects during the summer term.
 |
| ***Expertise***Teachers may lack experience or expertise in students’ areas of interest. Some schools have few technicians, or a high turnover of technical staff.  | * Shadow or discuss with a more experienced colleague.
* Ask for support from local universities *via* outreach officers or STEM ambassadors.
* Demonstrate that teachers are learning with their students.
* Take a responsive role, giving responsibility for most of the work to students.
* Make a case for greater technical support.
 |

**Conclusions**

Each teacher interviewed had a unique way of justifying and making open-ended project work ‘count’ in their institution. They all identified various barriers to this work, dependent upon context.

Enablers of open-ended investigative work in the curriculum reported by the teachers who were interviewed included teacher experience, support from the science department, support from school senior leadership, and external support. Reported challenges in providing access to open-ended investigative projects included those relating to the policy landscape, student responses to the work, and access to resources such as literature, laboratory space, equipment, and technical support. Time is a persistent issue – and where open-ended investigation is not a requirement of the specification it often relies on teachers working beyond timetabled hours. Some schools had creative ways of crediting teachers’ time on open-ended investigation.

There are, however, ways of making investigations ‘count’, which tended to be supported by senior leaders. These include relating it to the CPAC, linking with award schemes, offering it as an alternative to other scheduled teaching and learning activities, and encouraging students to write about their experiences on UCAS applications.

To increase the use of open-ended investigative project work at post-16, we recommend valuing teacher and technician time for project work through workload models and grant funding. There may be value in conducting research to test the belief held by some that open-ended investigative work has a positive impact on attainment at the post-16 level. Evidence to this effect may be compelling for teachers deciding whether to pursue such work. Assessment is an important driver for classroom practice, and a way to ensure that students have opportunities for open-ended investigation would be to require such work in post-16 examination specifications. However, were it to be included in specifications, care must be taken to avoid assessment methods that result in a formulaic approach to investigation.

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**Links**

CREST website [www.crestawards.org](http://www.crestawards.org)

CLEAPSS website [www.cleapss.org.uk](http://www.cleapss.org.uk)

1. Ofsted (The Office for Standards in Education, Children’s Services and Skills) holds state educational institutions accountable for the education and skills services provided for learners of all ages. www.gov.uk/government/organisations/ofsted/about [↑](#footnote-ref-1)
2. According to the English indices of deprivation www.gov.uk/government/statistics/english-indices-of-deprivation-2015 [↑](#footnote-ref-2)
3. CLEAPSS provide guidance on setting up and looking after a woodlice colony here: <http://science.cleapss.org.uk/Resource-Info/Setting-up-an-indoor-woodlice-colony.aspx> and on working with living animals here: <http://science.cleapss.org.uk/Resource/SSS073-Animals-living.pdf> [↑](#footnote-ref-3)
4. General Certificate of Secondary Education (GCSE) is the most common qualification taken by students in England at age 16. [↑](#footnote-ref-4)
5. The EPQ is a standalone level 3 qualification offered by six awarding bodies introduced in 2008, and worth up to a maximum of 28 UCAS (University and Colleges Admission Service) tariff points. [↑](#footnote-ref-5)
6. CREST Awards are administered by the British Science Association and allow students aged 5-19 to gain recognition for their own investigative work. [↑](#footnote-ref-6)
7. Pre-U is a pre-university qualification offered by Cambridge Assessment International Education (www.cambridgeinternational.org/programmes-and-qualifications/cambridge-advanced/cambridge-pre-u/) [↑](#footnote-ref-7)
8. www.stem.org.uk/stem-ambassadors [↑](#footnote-ref-8)
9. The Big Bang Science Fair is a competition where students can enter open-ended investigative projects. See www.thebigbangfair.co.uk [↑](#footnote-ref-9)
10. Business and Technology Education Council (BTEC) Nationals are vocational level 3 qualifications, see qualifications.pearson.com/en/qualifications/btec-nationals.html [↑](#footnote-ref-10)
11. The International Baccalaureate (IB) is an internationally recognised level 3 qualification, see [www.ibo.org](http://www.ibo.org). [↑](#footnote-ref-11)
12. CLEAPSS is recognised by the Health and Safety Executive and the Department for Education, and supports schools and colleges to fulfill their obligations under the health and safety at work act, particularly in relation to practical science. See www.cleapss.org.uk [↑](#footnote-ref-12)