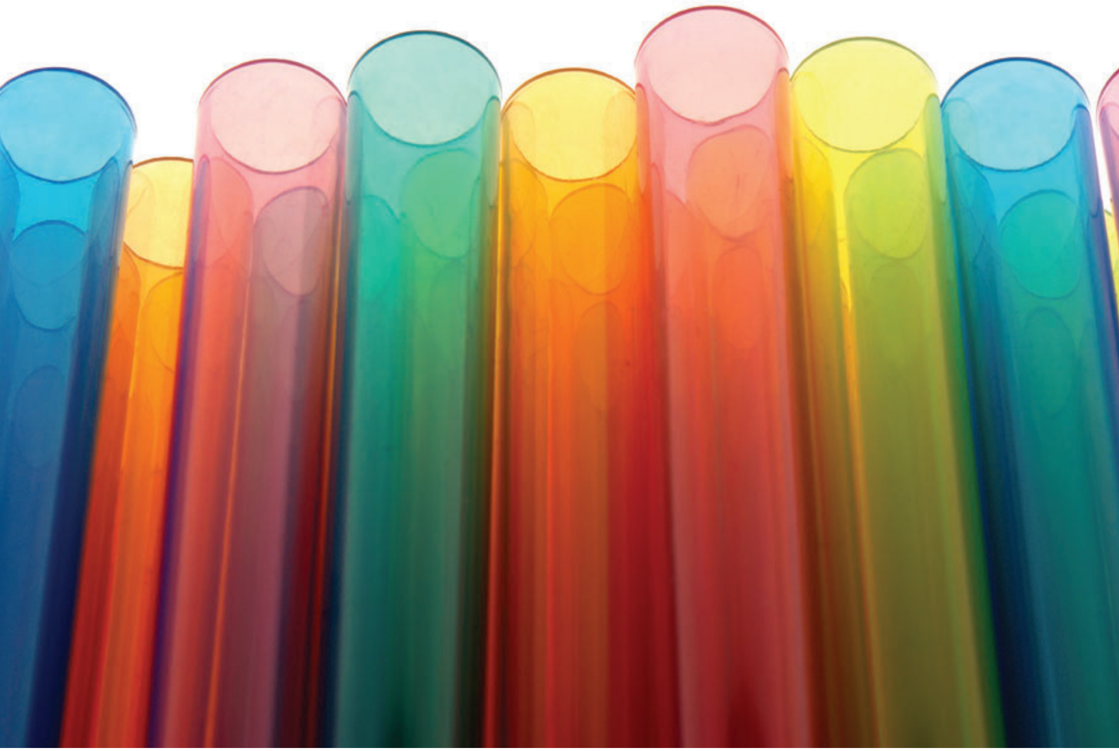
# Audit of Practical Work Undertaken by Undergraduate Bioscience Students across the UK Higher Education Sector



Society of Biology

Biochemical Society
Advancing Molecular Bioscience

# Audit of Practical Work undertaken by Undergraduate Bioscience Students across the UK Higher Education Sector

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# Steering group foreword

In 2012, the Biochemical Society's Policy Committee decided that a full review of the current status of undergraduate (UG) practical work across the UK Higher Education (HE) sector would be useful, particularly in the light of the introduction of higher fees, proposed A level reform, and reports from the Association of the British Pharmaceutical Industry of issues in respect of graduates' experimental skills. As a result, and with additional funding and input from the Higher Education Academy and the Society of Biology, research has been completed over 2013 and 2014 and the current report has been generated.

It is important to note that the report arises from questionnaires and telephone interviews with individual representatives of a range of UK Universities, and thus represents the combined sentiment of each respondent's subjective view. The majority of respondents expressed grave concerns that any further erosion of resource to provide practical work would have significant effects on the student experience and on the UK Biosciences graduate skills base. Another concern highlighted was the perception of academic staff that investing significant time in teaching activities and laboratory provision had potentially detrimental effects on their personal research and hence on promotion prospects. This is a serious issue for UK HE and the development of UG practical work, and needs to be addressed systematically by the sector.

The overall indications are that staff are happy with the levels of practical work available, although this varies widely across the sector. Some of this variation is because fieldwork has been omitted from the study (it already having been comprehensively reviewed previously ), but notwithstanding this, it would be interesting further to investigate the fine detail of student practical work experience from an "end user" perspective. Some suggestions as to future work include but are not limited to:

- Investigation of which techniques students on different courses actually perform, how frequently etc.
- Involvement of industrial partners in surveying the level and types of practical work carried out in Universities in respect of their requirements of graduates
- Comparisons of UK student experience with that of other EU and international students to gauge the provision in the UK against economic rivals

- Investigation of the perceptions of academics taking on students for postgraduate studies – how do UK graduates compare to international/EU candidates in terms of readiness for independent research?
- Repeating the survey on a regular basis (e.g. 3-5 years) to allow comparisons over time of provision. This will be particularly important in determining the impact of likely changes to the A level science syllabi which are proposed and which could significantly reduce practical work at school and thus preparedness of students for University work. This is already an issue for many institutions, and further reduction in school practical work will exacerbate the situation.

A very positive outcome of the survey has been the identification of good practice, and the willingness of respondents to share this. Some interesting Case Studies have thus been identified and are included for others to share.

In conclusion, the report shows a healthy current picture of UG practical work provision in UK HE, but bemoans the lack of preparation of students at school for this, and highlights the need to retain resourcing at least at current levels for this to continue.

[1] Alice L. Mauchline, Julie Peacock, and Julian R. Park: (2013) The Future of Bioscience Fieldwork in UK Higher Education. *Bioscience Education* **21**(1), 7-19. DOI: 10.11120/beej.2013.00014

# Executive summary

This audit sought to determine the state of practical provision across UK undergraduate degree programmes in the biosciences. It provides a useful benchmark to assess practical provision across different higher education institutions (HEIs) and can be used to monitor any changes to future provision.

The UK is a world leader in the life sciences and the growth of this sector is seen as a key strategic priority for the country. On 15 July 2014, the appointment of the UK's first Minister for Life Sciences further highlighted the importance placed on this sector.

Although the life sciences are becoming more multi-disciplinary and inter-disciplinary in nature, at their core is good experimental observation and exploration based on practical skills. It is generally accepted that excellent training in practical work will be key to the proper education of the next generation of life scientists, particularly in laboratory-based sub-disciplines related to the pharmaceutical, biotechnology and synthetic biology industries. However, the delivery of laboratory-based practical training has long faced challenges including high costs of equipment, consumables, facilities staff time, and lack of laboratory experience in schools. It is therefore important to investigate the nature and quantity of practical provision available and whether there are variations in provision at all levels and in the delivery of individual research projects. It is particularly useful to determine how the sector adapts to new challenges and highlight any innovations in the delivery of practical provision.

Thus, to establish a reference benchmark against which future trends in practical provision can be properly measured, we set out to estimate the current state of practical training in bioscience degree programmes across the UK Higher Education Institute (HEI) sector, in both "molecular" (M) biosciences and "whole organism" (WO) biology. Fieldwork was not included in our definition of practical work for the purposes of this study as a study of fieldwork provision in the biosciences had recently been conducted. Results were collected from the perspective of representatives at HEIs and should be considered in this context.

Our work focused specifically upon:

a) Estimating the amount of relevant practical training undertaken by students

b) Capturing the nature of the practical training that was reported to us

c) Capturing good practice and exemplars in the sector

d) Capturing the opinions of university teachers on the quality and quantity of delivery, on the changes to that provision over time, and on the threats to and opportunities for improving practical training

e) Capturing the opinions of university teachers on preparation in schools prior to students arriving at university

## Overall, we found that:

- Provision is varied across the sector and largely independent of the nature of the institution (pre-92 or post-92 institution), the nature of the degree programme ("molecular" (M) or "whole organism" (WO)), or the home country in which the institution is situated.
- An average bioscience degree programme involves a total of ~500 hours of relevant practical, laboratory-based training over 3 years.
- The quantity and quality of this provision is perceived by university teachers to be ***adequate*** or ***better*** across the sector.
- Significant challenges exist to maintaining and improving provision, but notable innovations in provision have also occurred.
- Poor preparation from school, allied with increasing student numbers, is perceived by university teachers to be a major threat to maintaining provision at its present standard.

## Practical training in years 1 and 2 (Scotland, years 2 and 3)

- Involves on average of 98 (+/- 39) hours per year of direct, hands-on practical work in "wet" laboratory-based bioscience.
- Students can work individually, in pairs, or in groups, with paired working being the most common mode of working.
- Is aimed at building practical experience and skills, with few opportunities for discovery or exploration. There are, however, a few notable exceptions/exemplars where discovery and exploration take place.
- Is supported by a variety of additional means, including data handling workshops, tutorials, demonstrations and online/virtual learning resources. Training can be

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distributed evenly throughout the academic year or focused in concentrated blocks; it can be part of every unit/module, or be limited to specialized courses.

## Final year wet-lab research project

- Is available in every degree program surveyed
- Is either compulsory (minority of HEIs) or are available to all students who choose it (majority of HEIs). In the latter case, innovative alternatives are often available.
- Is discovery based and exploratory, situated mostly within research labs, and designed by the supervisors (with only one notable exception where students are integral to designing their own bespoke project).
- Involves between 150 and 450 hours of laboratory work with most students working individually. Some HEIs are experimenting with pair or group working.

## Lab safety

- Training in lab safety is universal across the sector

## Online support/virtual learning

- The use of online support and virtual learning is not widespread in the sector and is seen as supplementary rather than as a replacement for hands-on practical work. The Open University was not included in this audit but is a notable exception.

## *In vivo* training

- In vivo training does not feature in most programs.

## Exemplars

- A number of notable exemplars were suggested from across the sector, pointing to significant innovation and evolution of practical training in the biosciences.

## Perceived changes from an HEI perspective

- Practical provision is perceived to have changed significantly over the last 5-10 years and mostly for the better. Respondents anticipate the next 5 years to be a period of more restrained but still largely positive change in practical provision. When interviewed, university teachers clearly perceive practical training to be a key priority to providing excellent education in the biosciences but are concerned about their capacity to cope with increasing student numbers: maintaining standards of practical provision may be a challenge:

*"The future will be same for students, but worse for staff"*

## Barriers

- There was near unanimity among university teachers on the perceived barriers limiting their practical provision:
    - Increasing student numbers
    - Limited resources (funding, laboratory space, equipment, staffing)
    - Maintaining the research project (reliance on cross-subsidy from research funding; limiting number and diversity of host research labs; conflicting demands of, and rewards for, teaching and research in an academic career)

## Preparation from School

- Preparation from school is perceived to be largely inadequate by university teachers. Institutions expect poor preparation and most have mechanisms in place to remedy this poor preparation. However, increasing student numbers are stretching the demands on these remedial mechanisms.
- New reformed A Levels, which will be introduced for first teaching in 2015, include changes to the way practical work is assessed. Therefore, monitoring this situation in the future will be important in order to see if the new A Levels will impact upon opinion regarding preparation from school

# Methodology

We sought to establish the state of practical training provided to bioscience undergraduate students across the UK Higher Education (HE) sector, to identify good practice through exemplars and to capture the opinions and experiences of university teachers. The audit was conducted in three stages:

## Stage 1: Questionnaire

A written questionnaire was designed by two lead researchers in consultation with the steering committee comprised of representatives from the Biochemical Society, the Society of Biology (and its special interest group, Heads of University Biosciences (HUBS)), and the Higher Education Academy (HEA). The questionnaire was designed to capture:

i) Quantitative data on the amount of practical provision in each degree programme

ii) Qualitative data on the nature of practical provision in each degree programme

iii) Exemplars (nominated by respondents or based on details given in the returns)

iv) Staff opinion/"barometer": the personal opinions/reflections of the university teachers completing the survey, on the state of practical training in their institution/ programme, and their perceptions of threats and opportunities.

In Summer 2013, the Society of Biology identified contacts in bioscience degree programmes across a variety of HEIs in the four home countries including both post-92 and pre-92 universities. Staff representing a total of 22 degree programmes across 16 universities agreed to take part in the survey and returned detailed written responses to the questionnaire (see Tables 1 and 2) in Summer and Autumn 2013. 11 pre-92 and 5 post-92 institutions were surveyed. The majority of universities responding to the survey are from England, with two returns from Scotland and one from Wales (see Tables 1 and 2). No response was received from the Northern Irish universities invited to take part.

For the purposes of the audit, bioscience degrees were divided into two general categories, "molecular" (*e.g.*, biochemistry, cell biology, molecular biology, gen etics) and "whole organism" (*e.g.*, anatomy, physiology, zoology, botany). In the remainder of the report, "molecular" degrees will be referred to as M degrees and "whole organism" as WO degrees. Contacts at each university were asked to select the degree group most applicable to their programme. Most universities identified one representative degree programme that fell within each category. A few universities appeared to teach a very focused range of the biosciences and hence supplied only one return. The fact that most universities had little difficulty identifying a representative M degree and a representative WO degree stream supports the validity of dividing bioscience degrees into these two broad camps. However, a number of universities reported a single degree as representing both streams. The distinction between M and WO degrees is not definitive, with some degrees covering the key characteristics of both. Such submissions were treated as M for the purposes of the audit (see Tables 1 and 2).

Quantitative data were extracted directly from the survey responses or estimated based on the information provided. Qualitative data were collated and summarized from the survey responses and broad trends and commonalities noted. Exemplars were either volunteered by respondents or were identified by the researchers from the information provided. Staff opinions were mostly captured by simple multiple choice questions (MCQs) with provision for respondents to expand using text boxes.

Fieldwork was not included in the data/information collected about practical work for the purposes of this study as a study of fieldwork provision in the biosciences had recently been conducted[3].

The staff opinions/barometer MCQ answers were analysed first and the results shared and discussed with the steering group. An analysis of the full survey responses was then prepared as a draft audit report and discussed with the steering group. We then selected specific cases to follow up by telephone interview in Spring 2014.

## Stage 2: Telephone interview/Case studies

Specific case studies were chosen to test the validity of the audit data submitted, and to probe in more depth the practical training provided across the sector. Pre-92 and post-92 institutions were represented in the follow-up interviews, and included degrees that the survey returns indicated as providing relatively high or relatively low amounts of practical training. The relevant survey respondents were e-mailed and invited to take part in telephone interviews, all agreed. Interviews followed a structured template agreed with the steering group, but ample time was left for open discussion. The interviews were

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[3] Alice L. Mauchline, Julie Peacock, and Julian R. Park: (2013) The Future of Bioscience Fieldwork in UK Higher Education. *Bioscience Education* **21**(1), 7-19. DOI: 10.11120/beej.2013.00014

summarised from notes or from transcripts of recorded calls. The case studies supported the quantitative analysis of the survey responses and provided explanations and depth not captured in the written survey. The results of the interviews were collated and incorporated into the audit report where appropriate.

## Stage 3: Exemplars and final report

Based on the data provided, specific exemplars were identified by the researchers. The relevant survey respondents were e-mailed in Spring 2014 and invited to contribute a written summary of the exemplary practice to be included in the final audit report. NOTE: Although the Open University had not been surveyed, we became aware of its distinctive and noteworthy approach to online and distance delivery of practical training.

**Table 1:** Degree courses designated by responding HEI as being M. Those courses identified by HEI as representing both M and WO degrees are shown in red and are included in all subsequent analyses as being M.

| HEI | Type | Title of Degree |
|---|---|---|
| Institution 1 | Pre-92 | BSc Biochemistry (3 yr) |
| Institution 2 | Pre-92 | BSc (Hons) Biochemistry |
| Institution 3 (Wales) | Pre -92 | Biochemistry |
| Institution 4 | Pre -92 | BSc Biological Sciences (Biochemistry) |
| Institution 5 | Pre -92 | Molecular and Cellular Biochemistry |
| Institution 6 | Pre -92 | BSc in Biomedical Sciences, Molecular |
| Institution 7 (Scotland) | Pre-92 | 4 year BSc (Hons) degree in Biochemistry |
| Institution 8 | Post-92 | BSc (Hons) Biological Sciences (Biochemistry and Microbiology) |
| Institution 9 | Post-92 | BSc (Hons) Biochemistry |
| Institution 10 | Post-92 | BSc (Hons) Biological Sciences |
| Institution 11 | Pre-92 | Human Biology Degree. HEI states that the title of this programme represents WO but the focus is largely below the 'whole organism' level. |
| Institution 2 | Pre-92 | Physiological Sciences |
| Institution 12 (Scotland) | Pre-92 | Biological Sciences |

**Table 2:** Degree courses designated by responding HEI as being WO.

| HEI | Type | Title of Responding Degree |
|---|---|---|
| Institution 4 | Pre-92 | BSc Biological Sciences (Zoology) |
| Institution 3 | Pre-92 | BSc Microbiology (3 Years) |
| Institution 7 (Scotland) | Pre-92 | BSc (Hons) Zoology |
| Institution 12 (Scotland) | Pre-92 | BSc (Hons) Biomedical Sciences (BIMS) |
| Institution 1 | Pre-92 | BSc Biological Sciences |
| Institution 6 | Pre-92 | BSc Wildlife Conservation with Zoo Biology |
| Institution 5 | Pre-92 | BA Biomedical Sciences. |
| Institution 13 | Post-92 | BSc (Hons.) Zoology |
| Institution 14 | Post-92 | BSc Biology |
| Institution 8 | Post-92 | BSc Microbiology |

A summary of the audit results was presented as a written document and as a PowerPoint presentation at the Spring 2014 meeting of the Heads of University Biosciences, a special interest group of the Society of Biology. Comments and feedback were incorporated into the final audit report.

# RESULTS

## 1: Practical work in the biosciences in years 1 and 2 (Scotland, years 2 and 3)

### 1.1: Time spent on practical work

Respondents estimated the amount of practical work undertaken by students in a number of ways: some provided schedules indicating each lab with content and timing, others provided overall numbers per year; some provided an average number of hours spent in lab per week and one provided an estimate of the % of time spent in labs.

We only analysed numerical data where numbers or numerical estimates were provided directly by the respondents or where respondents provided sufficient information to allow us to reasonably derive numbers. Our numerical analysis covers 12 of 13 M bioscience degrees, and 9 of 10 WO degrees surveyed.

Most respondents provided sufficiently detailed information to indicate that:

- They had properly identified practical work taking place in a laboratory (and were not including field work)
- They interpreted "practical work" to be equivalent to "hands on laboratory work" in most cases. This is universally the case for M bioscience degrees and largely the case for WO degrees.
- They were focusing mainly, if not exclusively, on hands-on wet work based in a laboratory setting and not on data handling tutorials or workshops. Demonstrations do not appear to be commonplace and, where they occur, are brief. Most respondents distinguished demonstrations from hands-on practical work.
- They attempted to distinguish practical training in bioscience from other practical training in cognate disciplines e.g. chemistry, even though such training can be an important component in building overall practical skills of a student. It is possible that some respondents focused only on practical training in their particular discipline.
- Many degree programs are organized on a modular basis in years 1 and 2 (Scotland, years 2 and 3). Many paths through these early years are therefore open to the students. In such cases, respondents reported practical training for the "typical" student path or for an average across the modules.

The estimates (hrs/yr) of hands-on, practical work undertaken by students in years 1 and 2 (Scotland, years 2 and 3) are shown for M degrees (Table 3) and WO degrees (Table 4).

**Table 3:** Practical training (total hrs/yr) for M degrees. Degrees are ordered by amount of practical work in year 1 (Scotland, year 2). Degrees from post-92 institutions are shaded. Degrees from universities based in Scotland are indicated by "S" and from Wales by "W".

| Mol. Degree | Year 1 | Year 2 |
|---|---|---|
| I S | 180 | 120 |
| II (post-92) | 140 | 120 |
| III | 120 | 140 |
| IV | 120 | nd |
| V | 120 | 120 |
| VI | 120 | 120 |
| VII (post-92) | 100 | nd |
| VIII W | 75 | 180 |
| IX | 75 | 80 |
| X S | 60 | 200 |
| XI (post-92) | 60 | 70 |
| XII | 39 | 45 |

## Molecular degrees

The AVERAGE contact hours for M degrees are (+/-standard deviation, SD):

**Year 1 (Scotland, year 2):** **101 (+/- 40) hrs/yr (n=12)**
**Year 2 (Scotland, year 3):** **120 (+/- 47) hrs/yr (n=10)**

Of the 10 degrees for which we have data over the two years, we can estimate the average exposure of students to practical work over the two years of their program:

**AVERAGE 2-yr TOTAL:** **219 (+/- 69) hrs (n=10)**

The data point to an average increase from 101 to 120 hours of practical work between years 1 and 2 (Scotland years 2 and 3). This is supported by the average pattern of activity within each degree program (see Table 3):

**60% (6/10) report more practical work in year 2 (Scotland, year 3)**
**20% (2/10) report the same amount of practical work over the two years**
**20% (2/10) report less practical work in year 2 (Scotland, year 3)**

| W-O Degree | Year 1 | Year 2 |
|---|---|---|
| I (post-92) | 150 | 180 |
| II (post-92) | 148 | 86 |
| III | 120 | 70 |
| IV S | 110 | 90 |
| V | 105 | 60 |
| VI S | 78 | 36 |
| VII W | 60 | 80 |
| VIII | 54 | 48 |
| IX (post-92) | 40 | 46 |

### Whole Organism degrees

The AVERAGE contact hours for WO degrees are (+/-standard deviation, SD):

**Year 1 (Scotland, year 2): 96 (+/- 40) hrs/yr (n=9)**
**Year 2 (Scotland, year 3): 77 (+/- 43) hrs/yr (n=9)**

Of the 9 degrees for which we have data over the two years, we can estimate the average exposure of students to practical work over the two years of their program:

**AVERAGE TOTAL contact: 173 (+/- 76) hrs (n=9)**

The data point to an average decrease from 96 to 77 hours of practical work between years 1 and 2 (Scotland, years 2 and 3). This is supported by the average pattern of activity within each degree program (see Table 4):

**22% (2/9) report more practical work in year 2 (Scotland, year 3)**
**11% (1/9) report the same amount of practical work over the two years**
**67% (6/9) report less practical work in year 2 (Scotland, year 3)**

It should be noted that many of the WO degree programs involve significant amounts of fieldwork that are relevant to their degrees but were excluded from this particular audit. The numbers here refer almost exclusively to wet laboratory work undertaken in the WO degrees.

**Total hours of practical provision over two years across all bioscience degrees**

We can estimate the total contact times over both years for 19 degree programs in total (10 from M and 9 from WO). We find that the average COMBINED contact time for practical work over the two years is:

**197 (+/- 74) hrs (n=19)**

### M *versus* WO degrees

In year 1 (Scotland, year 2), M *versus* WO degrees enjoy similar amounts of practical work, on average:

**M degrees = 101 (+/- 40) hrs/yr**

**WO degrees = 96 (+/- 40) hrs/yr**

Students taking M degrees undertake more practical work than those taking WO degrees in year 2 (Scotland, year 3), on average:

**M degrees = 120 (+/- 47) hrs/yr**

**WO degrees= 77 (+/- 43) hrs/yr**

[Note - Fieldwork can be a significant portion of many WO degrees and is not included here].

### Pre-92 versus post-92 institutions

There is no characteristic or distinguishing pattern for the amount of practical provision in M degrees in pre-92 versus post-92 institutions (see Table 3). Post-92 institutions (n=3) do appear to disperse to the higher and lower amounts of contact hours over the two years for WO degrees (see Table 4). Overall, our data are consistent with the pre-92 and post-92 institutions being indistinguishable with respect to the amount of practical work provided.

### Pattern across the UK home countries

We did not receive any returns from Northern Irish HEIs. However, we have returns from Scotland (2 Universities) and Wales (1 University): all of which submitted information for both a M and a WO degree. As shown in Tables 3 and 4, and taken together, the returns (n=6) from Scotland and Wales are well distributed and interspersed between returns from English universities when ranked by amount of practical work undertaken in year 1 (Scotland, year 2). Our data, although limited in size, provides no evidence for regional differences in the amount of practical provision in the bioscience degrees. Although it should be noted that year 1 of Scottish degrees was not included in the audit.

### 1.2: Mode of working

Students in years 1 and 2 (Scotland, years 2 and 3) can work individually, in pairs or in groups during practical sessions. For most degrees surveyed, and that provided clear information on this point, the predominant pattern of student working during practical sessions is stable over the two years, but the few programmes that change, do so in the direction of more individual or individualised work in the succeeding year (data not shown). Overall, the predominant mode of working across all degrees and both years is paired working, but with many programs dominated by group or individual working, or both (see Table 5). Even within group working, many programs involve each member of the group having individual roles and responsibilities.

**Table 5:** Predominant pattern of working in practical sessions across both degree types and both years.

| **Predominant pattern of working vs. number of degree years** | |
|---|---|
| Pair | 12 |
| Group | 8 |
| Mix: Group + Individual | 7 |
| Individual | 4 |

### 1.3: Nature of practical work

It is difficult for a single audit to capture the breath of practical work undertaken in any great detail. However, some very useful patterns can be gleaned from the results:

1) Most, if not all, of the practical work considered here involves laboratory work.
2) Most, if not all, of the work is hands-on.
3) Most practical provision in years 1 and 2 (Scotland, years 2 and 3) is aimed at building core and generic practical experience and skills, with few opportunities for discovery or exploration.
4) One or two respondents indicate that their programs are working towards introducing exploration-based practical work into practical training in these early years.
5) Many programs (7 of the 22 surveyed) already expose students to some exploration/ discovery work during practical training in one or both of these early years. Specifically:
    a. Some exploratory/discovery work as part of practical training in years 1 and 2 (Scotland, years 2 and 3) is mentioned in the returns from a number of institutions, e.g., Institution 8 (Microbiology), Institution 6 (Biomedical Sciences), Institution 3 (Microbiology), and Institution 2 (Physiology). (See exemplars for some examples)
    b. Students at Institution 12 (Biological Sciences) undertake mini projects over both years, and students are involved in planning work and in ordering equipment and reagents for upcoming work even in year 2 (rest of UK, year 1). (See exemplar 2)
    c. Institution 7 (Zoology) gives students some responsibility for experimental design during practical training in year 2 (rest of UK, year 1).

d. Institution 12 (Biomedical Sciences) runs a concentrated 21-hr exploratory "project" in Synthetic Biology in year 2 (rest-of-UK, year 1). This block is unusual in its scale and ambition. In addition, the focus on a cutting-edge and interdisciplinary branch of biology is particularly noteworthy and should be very motivating for such early-stage students (See exemplar 3).

### 1.4: Support of practical provision

Most practical provision in years 1 and 2 (Scotland, years 2 and 3) is supported by a variety of additional means, including data handling workshops, tutorials, demonstrations and online/virtual learning resources. This practice is universal but the nature of the support given varies across programs and institutions. An innovative use of online learning to support training before, and analysis after, a lab is discussed later.

### 1.5: Distribution of practical provision

The timing of delivery varies hugely within and between programmes: practical provision in years 1 and 2 (Scotland, years 2 and 3) can be distributed evenly throughout the year or focused in concentrated blocks; practical provision can be part of every unit/module or be limited to specialised courses. Most individual sessions appear to last up to 3 hours (half-day) but some programmes run day-long sessions, especially when mini-projects are being undertaken.

## 2. Final year research project

There was a wide variation in the data provided in response to this query, both from a quantitative and qualitative point of view. ***However, it is clearly evident that there is extensive provision for final year projects amongst the responding HEIs***. Generally, most research projects are situated within research labs, yet receive very little departmental funding for consumables, thus putting pressure on project supervisors to provide funding via their own research grants. Most project titles are provided by Principal Investigators/ Lecturers and are driven by research requirement. Occasionally students can put forward research titles but this practice is very rare. Most HEIs offer a good choice of wet (laboratory or fieldwork) versus dry (computer, literature) options for research projects. A minority of HEIs insist on students undertaking a wet laboratory project, unless medical grounds dictate otherwise.

## 2.1: Wet *versus* dry projects

'Wet' projects generally referred to those being carried out in wet laboratories (or in some cases, the 'field'), while 'dry' projects referred to literature reviews, computational projects, bioinformatics analyses, clinical audits, research questionnaires, or critical reviews of papers. In addition, some HEIs provided additional specialist projects. For example, Institution 3 (pre-92) provides a *'Scientific Engagement'* option for their final year projects, while final students at Institution 11 (pre-92) do not have to carry out a research project – instead they can opt for a *'Biology in Education*' Module if they exhibit active interest in teaching as a career.  Institution 4 (pre-92) also provide the option of an *'Educational Research'* project (ethics/school based).

***M degrees:*** Eight of the nine pre-92 HEIs report the general provision of wet (laboratory) or dry research projects. One pre-92 insists on ALL final year projects being wet laboratory based and research driven: only occasionally will they allow a dry project, and usually only on medical grounds to assist the student. Two of the post-92 HEIs provide both wet and dry projects with approximately 90% of students opting for wet projects. A third post-92 HEI insists on all projects being wet in nature (although this is a special case – see special points of interest/exemplars).

***WO degrees:*** Six of the seven pre-92 HEIs provide both wet and dry projects.  One pre-92 insists that ALL final year projects are based in a wet laboratory and are research driven. Two of the four responding post-92 HEIs permit wet and dry projects – the other two insist on wet projects.

Almost all wet research projects are provided with the intention of being 'research driven' and are supervised by active Principal Investigators. Indeed, one institution (pre-92, M) made a point that approximately 5% of their final year projects contribute to peer-reviewed publications. Institution 14 (Post-92) appears to be the only HEI surveyed that does not provide projects based on the research interests of the staff; students are required to design their own project.

Quantitative data pertaining to the choice of wet over dry projects was provided in some cases. Institution 1 (pre-92) stated that 50% of their projects were based in the wet laboratory while Institution 5 (pre-92), Institution 13 (post-92) and Institution 10 (post-92) state that 100% of their projects are wet. Our data suggest that, where there is a choice, approximately 75 – 90% of students opt for doing a wet project.

### 2.2: Individual or group

Research projects were universally based upon individual students, although a comment was made by Institution 3 (pre-92) that their projects are mostly individual with some group projects starting to appear. The Institution 3 respondent noted that this practice is likely to become more frequent in an effort to accommodate larger class sizes. Institution 1 (pre-92) also appear to support projects in 'pairs'. While lab work can be carried out in pairs or groups, the write-up is supposed to be an individual's own work.

### 2.3: Timing

Quantitative data was limited but suggests that the time spent on final year research projects varies widely from 150 hours to 450 hours with a mean of 249 hours for M degree projects (n = 5) and 316 hours for WO degree projects (n = 3). When WO and M degrees were viewed collectively, the mean time spent on a research project at a Pre-92 HEI was 300 hours (n = 6), compared to 198 hours at a Post-92 HEI (n = 2, low sample size).

### 2.4: Choice of project

HEIs generally report that sufficient project titles are provided to students such that a reasonable choice is available. Students generally provide a list of preferences (up to six titles) from a collated list of project titles. Allocations are sometimes made using second year exam grades (Scotland, year 3) (i.e., high ranking students are more likely to get the project of their choice). Generally speaking, module leaders tend to make the allocations, although sometimes a committee is involved and students are asked to provide a short statement/rationale of why they would like to study a specific topic (e.g., at a pre-92). This latter pre-92 degree also appears to consider student career aspirations when making project allocations. A post-92 uses a random algorithm to allocate projects (this is not performance based). Projects are chosen at another pre-92 by an online survey and based upon marks obtained in the second year. As a reward for excellence, the top ranked student is guaranteed the project of his/her choice. A post-92 degree reports that their allocation system changes regularly and is a "never-ending battle". Overall, however, it is pleasing that in general, HEIs allow the students to pick their project/supervisor, rather than the reverse process.

A pre-92 states that approximately 10% of their students are not allocated a project on the first round and need to choose differing titles in a second round. Another states that 90% of their students get their first choice title but aim for students to get either first or second choice.  At a post-92 degree, allocations are not a problem as the students design their own project (but this has the disadvantage that the project does not necessarily link to staff research interests).

### 2.5: Consumable funding

All departments provide some aspect of funding to assist with the cost of providing laboratory projects, although many rely upon grant funding from principal investigators. 'Dry' projects are generally not funded. Several HEIs did not providing quantitative data for this query.

**M degrees: pre-92 HEIs provide £100 - £600 per project (mean of £383, n = 6)**

**M degrees: post-92 HEIs claim that costs are covered by Department but do not provide quantitative data (n = 3)**

**WO degrees: pre-92 HEIs provide £250 - £400 (mean of £350, n = 3)**

**WO degrees: post-92 HEIs claim that costs are covered by their department but do not provide quantitative data with just one exception (£300 per student).**

### 2.6: Special points of interest/exemplars

1. Institution 3 (pre-92, M) provide a *'Scientific Engagement'* option for their final year projects
2. Final students at Institution 11 (pre-92, M) do not have to carry out a research project – instead they can opt for a *'Biology in Education'* module if they exhibit active interest in teaching as a career.
3. Institution 4 (pre-92, M) provides the option of an *'Educational Research'* project (ethics/school based).
4. Institution 5 (pre-92, M) students have the option of ERASMUS placements in Europe, or placement at Princeton University, USA.
5. Institution 10 (post-92, M) has developed a very interesting strategy that promotes wet laboratory activity. Students take a second year course ('Science Research Proposal') in which they design their own research project proposal geared to enhance their CV. Students are provided with guidance on Full Economic Costing (fEC) , health and safety, ethics, and use a proposal template adapted from the Biotechnology and Biological Sciences Research Council (BBSRC). This proposal is then costed by academic staff and then discussed at a research fair (which involves

academic staff, enterprise staff, careers service etc). The student subsequently carries out the proposal as a final year project. Students submit their findings in the style of an academic paper and are encouraged to publish in under/postgraduate research journals such as *'Bioscience Horizons'* (see Exemplars section later).

6. Institution 2 (pre-92) have developed a 'University Ambassadors Scheme' in which students undertake work within the school as a final year project. Allocations for this are made via competitive interview (see Exemplars section later).

## 3: Training in laboratory safety

Survey results were very encouraging in that ***ALL*** responding HEIs appear to take laboratory safety training very seriously. Generally, all degree courses involve some form of compulsory induction lecture/talk/workshop at the beginning of the course (which includes a 'School Level' training course at Institution 11, pre-92, M and WO), progressive development throughout the degree (*via* written and verbal instruction prior to each practical session), and further more specific training prior to final year research project training. HEIs appear to take great care in ensuring all laboratory sessions are risk assessed and that students understand the requirements of risk assessment. In several cases, HEIs provide specific modules or courses (e.g. 'Research Techniques', 'Biological Methods' or 'Quality Management') that feature laboratory safety (e.g. Institution 3, Institution 10).

In many cases, HEIs stipulate the need for close supervision and feedback (e.g., Institution 5 and Institution 13). Assessment is sometimes used to encourage safety training, often using an online format (see below).

### 3.1: Assessment and online training

Institution 2 (pre-92, M) regularly utilise online safety quizzes that students must pass (if they don't, remedial training is provided). Institution 3 (pre-92, M) incorporate a compulsory second year module entitled 'Research Techniques' (a mark of 70% or higher is required to pass this module). Online quizzes are also used regularly by Institution 8 (post-92, WO). Institution 12 (pre-92, WO) use an online safety questionnaire to prepare students for their final research project.

### 3.2: Specific aspects of research project safety training

One pre-92 requires all students, irrespective of project type, to attend a safety awareness lecture, pass a safety awareness test, and undertake a risk assessment of a common, relevant laboratory procedure (e.g., use of agarose or polyacrylamide electrophoresis). Supervisors of final year projects, irrespective of HEI, provide project-specific safety training.

**3.3: Exemplars:**

1. Institution 5 (post-92, M). In the second year, students attend a risk assessment lecture. They then complete a risk assessment form for their final year project aided by one-to-one discussion with the project supervisor.
2. Institution 10 (post-92, M) have developed a very interesting system in which students are required to undertake standard operating procedure (SOP) testing for laboratory practicals. These consist of a series of practical and theoretical tests which are assessed by academic members of staff to ensure student understanding of Good Laboratory Practice (GLP) and Health & Safety.
3. Institution 13 (post-92, WO) make a very strong point that "one can talk as much as you like, provide as much written and computer-based support as you like, but the most effective guidance is given as you walk around the laboratory and actively engage students individually". Final year students must also complete their own COSHH forms before they are able to begin their research projects.
4. Institution 8 (post-92, WO). All final year students must prepare COSHH and risk assessment forms for their own project prior to starting work in the laboratory. Institution 3 (pre-92, WO) final year students must also write their own basic risk assessments but it does not appear that these assessments relate to the student's specific research project.
5. Institution 2 (pre-92, M and WO) was the only responding HEI to stipulate that while laboratory safety is an explicit part of every practical, early practical sessions were chosen so that they offer little risk while those that require a keen awareness of hazards and the minimisation of risk come later.

In summary, laboratory safety training is taken very seriously by all of the HEIs surveyed at this time and involves early induction, followed by the progressive development of training (involving quality management, health and safety, risk assessment and COSHH), followed by specific training for the final year research project (at the hands of the project supervisor). Safety training is generally carried out by academic staff and in the best cases, is enforced by assessment. Online resources appear to be used only for questionnaires and periodic assessment. There was no significant difference in the stance of pre- versus post-92 Universities, except for the fact that most of the exemplars listed here arose from post-92 institutions.

## 4: Computer simulations and online training

**Nine HEIs reported that they do not use online training (or have very little involvement with this style of teaching) at the present time. Of these, six were pre-92 and three were post-92.** One pre-92 notes that there is significant scope for online training but does not mention whether this is likely to happen. Another made a strong point that they don't use computer simulations for practical training ("it is all for real").

The remaining HEIs all utilised online training/computer simulation in their practical provision to some extent. Institution 2 (pre-92, M) reported that their use of online training was 'huge and transformative' (see Exemplars section later). This resource includes simulations of laboratory equipment to help students recognise equipment and understand how it should be used (before the actual class). Institution 2 reported that this has significantly improved student understanding, engagement and achievement. Institution 1 (pre-92, M) also make extensive use of online systems throughout the three years of teaching (molecular graphics and dynamics, DNA and protein sequence analysis, graph plotting, statistical analysis etc). Institution 11 (pre-92, M and WO) use computer simulations for evolutionary biology teaching and bioinformatics (research projects). Institution 5 (pre-92, M) report that computer-based training is very useful for methodology training (immunology, enzyme kinetics, and protein structure) in that it allows students to visualise the effects of changing experimental parameters (conditions, reagent concentrations etc). Institution 6 (pre-92, WO) report the prominent use of computers in their curriculum (geographic information systems, population biology). Institution 8 (post-92, M) and Institution 12 (pre-92, WO) also make extensive use of computer-based teaching for a variety of topics. Institution 12 have developed a range of specific Flash-based tutorials that are accessed via their virtual learning environment (VLE) (e.g., RatCVS, Virtual Rat Program), while Institution 8 use computer technology for methodology, bioinformatics, molecular biology and protein structure, and in particular, 'frog leg' and 'frog heart' – programmes that use online assessment. The module leader of these specific programs claims that the advantage of this approach relates to animal welfare, and that while some students agree, others would prefer a 'real session'. There are plans to replace one simulation with a real practical based on insect physiology.

Institution 8 (post-92, WO) uses computer-based material extensively on their microbiology degree. **In addition, all undergraduate laboratory classes are paperless with students using computer tablets during the class.**

**A common thread running through the responses was that online training is not**

**expected to replace laboratory work but rather is seen as complementary to and enhancing of the wet laboratory experience**. However, this report acknowledges one clear exception where online training is taking a more prominent role. *The Open University, although not formally surveyed in this audit, has recently opted for online and distance delivery of **all** of its practical training in the biosciences*. This radical deviation from the standard practice within the sector will be interesting and useful to follow.

## 5: *In vivo* practical training

Seven HEIs reported that they DO NOT support *in vivo* work in any context. Of these HEIs, four were pre-92, and three were post-92. The remaining institutions reported that their respective degrees incorporated at least some aspect of *in vivo* training.

Actual hands-on *in vivo* work involving vertebrates was very rare, and reported by only four institutions: three pre-92, and one post-92. Generally, this experience referred to final year research projects supervised by research groups, and included relevant Home Office training. One pre-92 selects students for such projects if they have expressed an interest in continuing on to a higher degree after graduation. Two other only deploy *in vivo* training as part of pharmacological modules. At Institution 12, final year students have the opportunity to apply for an *in vivo* course offered by other institutions and run by the Physiological Society and the British Pharmacological Society. One pre-92 university provides some vertebrate work (using hamsters) but this is non-invasive and only behavioural in nature.

Generally, the remaining institutions only provide minimal *in vivo* experience, involving invertebrates such as zebrafish embryos, daphnia, polychaete worms, insects, and fish. Institution 12 carries out some human physiology experiments (nerve conduction, ECG, renal and respiratory studies, glucose tolerance tests, metabolic rate, and salivary flow). One pre-92 degree includes some fieldwork studies while another involves dissection of dead specimens only. One post-92 degree incorporates several visits to a local zoo with some behavioural work.

Generally, it appears that most of the respondents take into consideration that students do require, and appreciate, at least some *in vivo* work, but take due care in the design of such material to respect the sensitive nature of such work. Only a select group of students, those that appear destined for a higher research degree, appear to have the option of experiencing scientific procedures that are regulated by the Home Office. In these cases, students appear to be well supervised, and receive appropriate training.

## 6: Barriers to improving practical provision

Responses to this survey query were very clear, irrespective of geographical region, HEI, and degree type. ***Recurrent concerns related to funding, the availability of laboratory space/equipment, the demands made upon staff time, and increasing class size. Providing a suitable number, and diversity, of research projects was a common problem. A strong theme was the tension created between research and teaching demands***. A pre-92 in particular noted that it often had to defend the use of laboratory space for teaching. Several HEIs noted problems related to research inertia as a result of academic staff being routinely utilised in practical teaching. Increased class size was a major issue and in several cases had led to the regular need for staff to repeat practical sessions in order to convey teaching objectives in a safe and clear manner. Several HEIs made it clear that in order to minimise demands on academic staff, the same practical sessions were repeated year on year (this was defended by good student feedback and annual appraisal). Devising new practical sessions was a particular problem for four HEIs (3 pre-92 and 1 post-92). One pre-92 HEI reported that student diversity was a problem and that it was difficult to cater for such diversity in large class sizes given current resources (lab space, funding etc).

Some of the post-92 HEIs had a more positive approach to this query. One stated that they are currently well supported but would need new equipment as class sizes increased. Another stated that although funding is a problem, they constantly aim to adapt laboratory provision to meet current developments in the field. Another stated quite forcefully that funding is a problem and is a major concern for the future of its delivery.

One pre-92 indicated that the lack of recognition for teaching causes staffing problems. Another pre-92 indicated that staff involved in practical provision routinely work unpaid overtime.

The responses from the survey show there is widespread perception that practical skills are not being particularly well developed during secondary education. If this situation does not improve or becomes worse there could be a greater strain on resources for teaching practical provision in higher education.

## 7: Opportunities for improving practical provision

***A recurrent theme (irrespective of degree type) was the availability of laboratory space, the availability of academic staff, and staff:student ratio***. Several HEIs (mostly pre-92) suggest the increased use of online/distant learning/bioinformatics. Only one post-92 HEI make a big point of improved use of information technology, *via* adopting scientific Apps on student tablets. Another post-92 suggests the use of more pre-laboratory sessions (including video material) to improve engagement in subsequent lab sessions. A pre-92 HEI also plans to improve student independence by the improved use of pre-laboratory activities.

In terms of staffing, one pre-92 HEI intends to exploit post-doctoral researchers while another is contemplating more Summer internships for students in research laboratories. A pre-92 HEI is considering the increased use of peer instruction by using good final year students to help teach more junior students. A post-92 HEI reports the urgent need to increase the number of student placements (only a third of students are allocated placements at the current time). Finally, another post-92 is contemplating the use of school/college liaison to improve practical skills and contact time.

The availability of laboratory space was mentioned by many HEIs but solutions were not volunteered. One pre-92 HEI is considering collaboration with other institutions (perhaps via exchange programmes) to maximise the use of available laboratory resources. Better cooperation between institutions may address many of the space and equipment concerns identified by this audit.

Staff at Institution 8 (post-92) reported a novel solution to freeing staff time: staff are allowed to take sabbatical leave in order to develop new methods and materials to improve bioscience practical provision.

## 8: Barometer of staff opinion

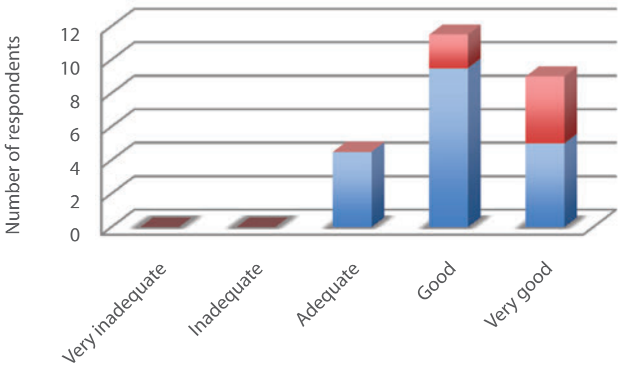
In this section, we focus on the answers to the MCQs (Q10-Q15) asked in the written survey. These questions required the respondents to choose from the available answers the one that best represents their ***personal opinion***. These answers are thus subjective, representing the views of those who completed the audit. Nonetheless, analysis of the answers to the MCQs gives a snapshot of the state of practical provision as perceived by the community of university teachers themselves.

**NOTE:** in some cases, respondents choose two of the available options. In such cases, we ascribed 0.5 of a point to each of the selected responses.

### 8.1: Overall quantity of practical training

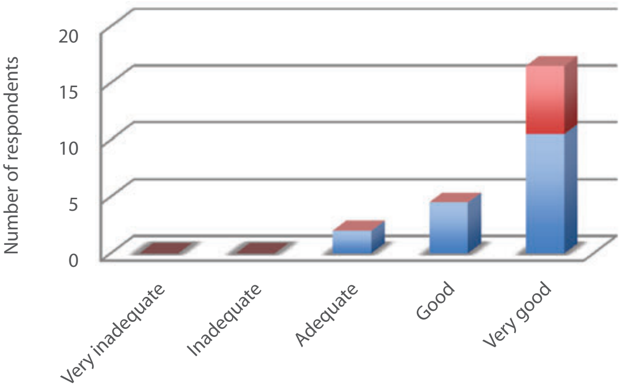
Most respondents clearly perceive the **amount** of practical training to be either good or very good. This positive trend was true for pre-92 and post-92 institutions (Figure 1) as well as for M and WO degrees (data not shown).

**Figure 1. Overall quantity of practical training provided.** Responses are shown by institution type: pre-92 (blue); post-92 (red). No significant difference was noted between M and WO degrees (data not shown)




## 8.2: Overall quality of practical training

**Figure 2. Overall quality of practical training provided.** Responses are shown by institution type: pre-92 (blue); post-92 (red). No significant difference was noted between M and WO degrees (data not shown)




The perceived **quality** of practical provision is rated as being "very good" by the majority of respondents (Figure 2). This very positive trend was true for both pre-92 and post-92 institutions, but was most dramatic for the post-92 institutions surveyed (Figure 2).

## 8.3. Funding and staffing of practical provision

**Figure 3. Funding and staffing of practical provision.** Responses are shown by institution type: pre-92 (blue); post-92 (red).

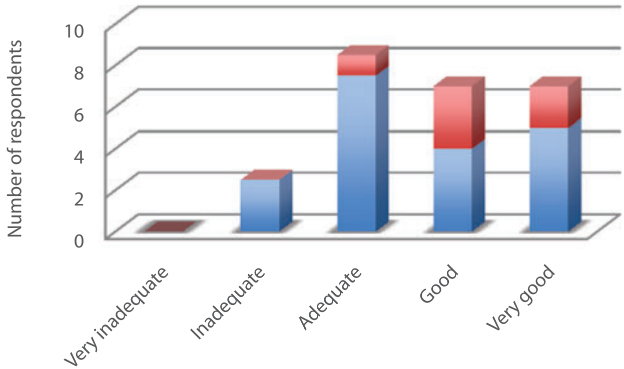
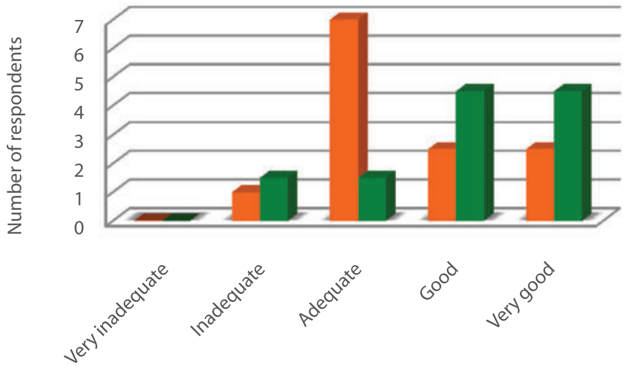



**Figure 4. Funding and staffing of practical provision.** Responses are shown by degree type: M (orange); WO (green).

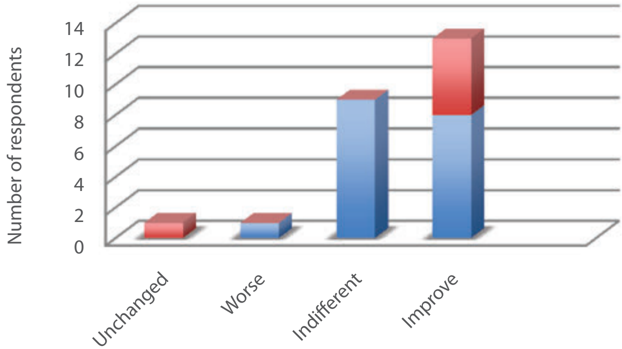



The perceived state of funding for, and staffing of, practical provision mostly ranged from adequate to very good, with only a few programs feeling it to be inadequate (Figures 3 and 4). This trend is true for both pre-92 and post-92 institutions (Figure 3).

Overall, the perception of funding and staffing appears to be more positive for WO degrees than for M degrees, with most of the latter rated merely as being "adequate" (Figure 4). However, respondents indicated there is no room for complacency, especially for M degrees for which practical training is likely to be more intricate, demanding, and expensive.

## 8.4: How has practical training changed over last 5 - 10 years?

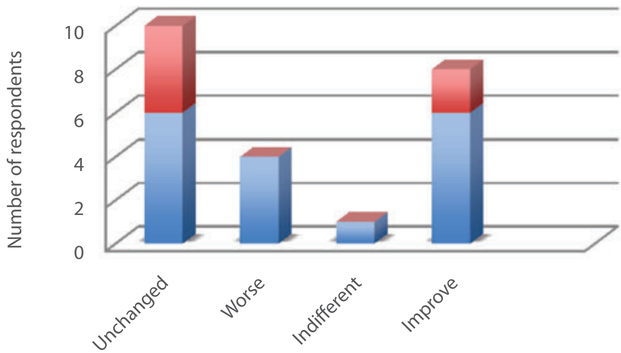
**Figure 5. How has practical training changed over last 5 - 10 years?** Responses are shown by institution type: pre-92 (blue); post-92 (red). No significant difference was noted between M and WO degrees (data not shown).




Overall, respondents indicate that change had dominated their practical provision over the last 5-10 years, with over half of responses feeling that their provision has improved and most of the rest that it has changed but not diminished (Figure 5). The post-92 sector seems to respond more positively than the pre-92 sector. The last decade has thus been one of change in practical provision in the biosciences across the UK HEIs, and according to respondents, much more for the better than for the worse.

## 8.5: What changes to practical training are likely in next 5 years?

**Figure 6. What changes to practical training are likely in next 5 years?** Responses are shown by institution type: pre-92 (blue); post-92 (red). No significant difference was noted between M and WO degrees (data not shown).

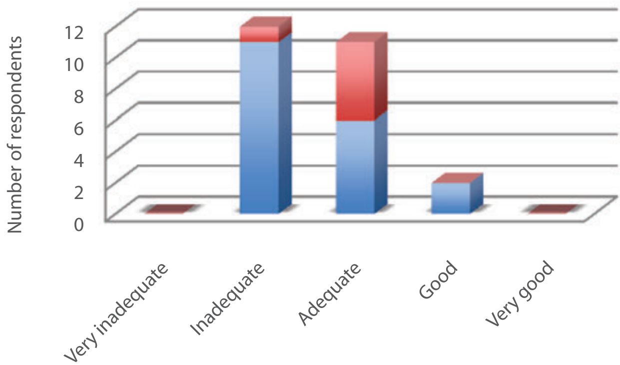


The respondents see the next five years as a time of consolidation and improvement – with answers fairly evenly divided between "unchanged" and "improve" (Figure 6). This anticipation of a period of restrained improvement is shared across the sector (both pre-92 and post-92 institutions: Figure 6) and across degree types (data not shown).

A minority of respondents, all four at pre-92 institutions, felt more pessimistic about the near future, feeling that their provision would worsen over the next 5 years.

### 8.6: Are your bioscience students well prepared from school?

**Figure 7. Are your bioscience students well prepared from school?** Responses are shown by institution type: pre-92 (blue); post-92 (red). No significant difference was noted between M and WO degrees (data not shown).




The responses are mainly split between preparation from school being adequate and being inadequate. Only two of the responses indicate that preparation was better than adequate (Figure 7). The survey is thus pointing to practical skills not being particularly well developed during secondary education.

The concern about student preparation is echoed elsewhere in this survey, e.g. in case study interviews where the respondents who rated school preparation as "adequate" did so only because they accept that preparation is patchy and often very poor for a subset of students: the level of preparation is thus not surprising to them. The benchmark for "adequate" appears to be set rather low.

# Conclusion

This audit provides a useful benchmark against which different HEIs can compare their practical provision in undergraduate bioscience degrees, both now and in the future. The perspective from HEI representatives of their own provision is generally positive. Increasing student numbers and poor preparation from school do however seem to be of concern to some respondents, with the quality of future provision in question without maintenance sufficient of resources. Practical provision should continue to be monitored to ensure the UK continues to produce leading life science graduates who support the UK economy.

# Exemplars

Particular examples of good or innovative practice were identified or indicated in the audit returns. The relevant audit respondents were contacted and invited to submit a description of the exemplary practice. In some cases, additional or alternative colleagues at these institutions contributed to the final descriptions. In all, five exemplars (of the six invited) were submitted for inclusion in this report (Exemplars 1-5 below).

## Exemplar 1

***Research Proposal***
***Teesside University, Biological Sciences degree***

Students undertake the "Science Research Proposal" module (10 credits) in the second year of their degree, followed by the "Science Research Project" module (30 credits) in their final year. In the first of these modules, students produce a research proposal for their final year "Science Research Project". This follows modified guidelines provided by the BBSRC and contains:

- details of the project, targeted at a specialist audience and the general public
- a full economic costing of the project
- health and safety and risk assessment documentation
- ethical clearance forms
- a targeted CV

Lectures and tutorials provide guidance and support on key elements of the proposal and permit delivery from departments outside the school, drawing on relevant external expertise. Following lecture 1, a Research Project Fair provides time for discussion of project areas with tutors. Projects are then allocated based on ranked preferences. Lectures are:

1. Introduction to the research proposal and project selection procedure
2. Writing a research proposal – delivered by research and enterprise staff to help students define the potential for commercialisation and impact of their projects.
3. Costing – to ensure students consider the financial implications of their proposed study

4. Ethics/ethical codes of conduct – delivered by the Chair of the Schools' Research Ethics Committee
5. Health and safety/risk assessment statements – delivered by technical staff who introduce the databases/processes which support the development of effective risk assessments
6. Producing a targeted CV – delivered by the Careers Service

As the risk assessment(s), project planning and ethical clearance have all been completed during their second year, students can start their "Science Research Project" laboratory work at the very start of the third year.

To develop their communication skills and understanding of research culture, students present their research via four primary routes:

1. Five minute presentation – delivered, prior to the winter break, to peers and discipline-based academics. Students showcase their work to-date and staff and students provide feedback on progress made.
2. Poster and abstract – at the School Poster Day in March. The event is attended by academic staff, external examiners and invited professionals.
3. Academic paper in the style of a scientific journal related to their discipline – where appropriate, students are encouraged to disseminate their work at external events or the potential for their work to be published in journals, such as those which specialise in publishing undergraduate research (e.g. Bioscience Horizons).
4. Students maintain systematic and reliable records of their research. These are reviewed regularly by the supervisor and assessed at the end of the project.

## Exemplar 2

***Graduate attributes embedded within the curriculum in year 1 and year 2 (Rest of UK, year 1)***
***University of Dundee, Biological and Biomedical Sciences degrees***

**Background:**

The University of Dundee introduced their new curriculum for all Life sciences undergraduate programmes in September 2011. In the design of the new curriculum they wanted **to address many of the employers concerns about graduate skills** and introduce these from the start with reinforcement in each semester.

The skills they aimed to incorporate were practical confidence, planning skills, time management, communication (both oral and written) and research skills. Their overall aim is to produce "**a confident, self-reflective, critical thinking scientist, able to solve problems and work in a global context.**"

**The revised curriculum:**

All students follow a core curriculum for the first two years regardless of their intended specialist programme which has been designed with a reduction in lectures and a large increase in practical and workshop sessions. Students spend 60 hours per semester in the laboratory with 30 hours of associated workshops. In each semester students take two practical modules, one in which they learn set techniques and associated skills such as data analysis in workshop sessions. The second practical module is project based. The project sessions allow students the chance to **explore various aspects of laboratory work and in these must plan and organise their sequence of work. This includes ordering equipment and reagents for the coming week from technical staff, and having group meetings to plan out their work and assign tasks.**

In semester one of year one, students start with two short 4 week long projects after an initial practical session introducing the project and associated protocols. The projects introduce them to concepts of experimental design, record keeping, group working and the skills of making solutions and carrying out TLC. In semester two they undertake an eight week project based around investigating the activity of amylases under various experimental conditions of their choice. **During this project the skills are project planning, time management and ordering whilst making their own buffers and designing their own experiments including controls and repeats.** Workshops running alongside the projects give them skills in statistics (using R), data presentation, using modeling programs (PyMol and Chimera), designing posters and relevant numerical skills. During each semester students keep a record of both their practical and generic skills using their PDP on Blackboard. They must reflect on their progress and meet with their adviser of studies each semester to discuss these and where they need to improve.

In the set practicals they learn techniques such as column chromatography, gel electrophoresis, aseptic techniques for microbiology and microscopy.

In year two, semester one this pattern of set and project practical modules continues with a further two four week projects one of which introduces basic skills in organic synthesis techniques. In semester two they carry out an eight week project in synthetic biology (see

Exemplar 3) which includes current molecular biology techniques.

**Outcome:**

By the end of year two University of Dundee Life Science students are confident in the laboratory and ready to tackle complex practical tasks in year three which completes their preparation for independent research projects in their final Honours year. Students enjoy spending so much time in the laboratory and the responsibility they have for their own work and the University see this reflected in the standard of associated coursework. They have come to University to study Life Sciences because they are interested in learning more and the projects allow them to explore topics in an interesting and independent manner while they also gain a huge amount of practise in the practical skills required in the sector today.

## Exemplar 3

***Synthetic Biology – an open level 2 (Rest-of-UK, level 1) practical project***
***University of Dundee, Biological and Biomedical Sciences degrees***

**Background:**

This project, now in its second year, is part of a level 2 semester 2 module (Laboratory and Research Skills 2C) which is compulsory for all Life Science students at the University of Dundee. In 2012/13 240 students took this module, the current class (2013/2014) comprises 160 students.

**The aims and objectives of the project are**

- To provide students with an opportunity to learn standard techniques in molecular biology
- To provide students with an opportunity to plan, conduct, and report on a mini research project
- To allow students to revisit a number of basic molecular biology concepts relating to the regulation of gene expression from an experimental point of view

Students (in groups of 4) are given the **task**:

- **To design a synthetic biology device** based on standardised iGEM biobricks (International Genetically Engineered Machine BioBrick registry of parts: http://parts.igem.org/Help:An_Introduction_to_BioBricks)

The concepts are initially introduced in a lecture to the whole class. Students have to produce a project plan explaining:

- Which parts they needed
- What their device is supposed to do
- How they plan to test it.

**Students then have one or two 3-hour practical sessions per week for a whole semester to work on the project**. The work includes isolation of plasmid DNA, digesting the DNA with restriction enzymes, setting up ligation reactions, making E. coli cells competent, transforming ligation mixtures into competent cells, and testing transformants for successful cloning by colony PCR.

One of the key challenges is that groups have to **plan in advance what they are going to do in their next lab session**, and have to fill in and submit order forms to allow technical staff to plan and prepare equipment and reagents for each session. Students also have to learn how to label their reagents appropriately so that they can be found again when required, sometimes weeks after they are initially generated.

Practical sessions are mostly supervised by senior demonstrators, with occasional help from academic staff.

Students are assessed by a written group project report in the style of a FEBS Letters paper, an individual abstract, and a poster aimed at the informed lay people. Posters are displayed in dedicated poster sessions and were peer-assessed.

### Challenges

The following challenges were identified during the first instalment of the project: protocols need to be detailed enough so that students can work through them independently. Demonstrators need to be familiar with all techniques and the theoretical background of the project so that they can help students not only technically, but also to make decisions and plan ahead. Logistics in the lab need to be planned in detail, technicians need to know in advance what reagents and equipment are required in a particular session.

Senior demonstrators now report that the same cohort of students are very confident in their level 3 practical projects, and we believe that students learned a great deal about molecular biology research, associated techniques, and how to plan a project.

## Exemplar 4

***The Undergraduate Ambassador Scheme (UAS)***
***University of Bristol, Physiological Sciences***

Post-secondary science education is characterised by a bumpy transition from being a scholar-historian of scientific discovery towards being a competent scientist. In many ways undergraduate students in the sciences are apprentice scientists, learning by observation, instruction and application. The final year research project is regarded as the apprentice piece by which students' mastery and autonomy is judged. Recent increases in the ratio of students to staff challenges the ability to provide the laboratory-based research experience of traditional final year projects. Moreover, the proportion of science students who intend a career outside of science has increased and for them the experience of a laboratory-based research project has limited significance.

The **Undergraduate Ambassador Scheme** (UAS, http://www.uas.ac.uk), developed in 2002 by Simon Singh (writer and broadcaster) in collaboration with Hugh Mason (BBC producer), provides an attractive alternative to laboratory-based final year research projects. The UAS initiative was supported by the Department for Education and Skills (now Department for Education) funding to set up a non-profit company to provide advice and support to departments that wished to set up credit-bearing units based on the UAS model. The stated aim of the UAS scheme was to **increase the quantity and quality** of i) students entering STEM HE programmes and ii) STEM graduates training to be teachers. Allied aims are the establishment of closer ties between University staff in STEM departments and science teachers in their local schools. In a practical sense, departments are at liberty to tailor the UAS model to create units in any year of study, the only proviso being an obligation to consider the founding principles of the UAS; principles that seek to ensure that there are benefits to all stakeholders, specifically, the schools and school teachers, the school pupils, the undergraduate students and the universities.

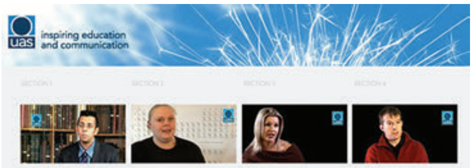
In Physiology and Pharmacology UAS placements are competitive and decided by interview. The University of Bristol also organise a half day training event run by a PGCE Science Tutor from the Graduate School of Education that focuses mainly on aspects of classroom management and the National Curriculum.

The UAS scheme encourages involvement in both primary and secondary education although in Physiology and Pharmacology UAS projects are exclusively based in secondary schools. The UAS-based final year research project they have developed has three strands;

Ambassadorial, Teaching and Research which carry default weightings in the dissertation of 10, 35 and 50%, respectively (the teacher's assessment carries 5%). Dissertations of UAS-based projects represent the same period of time (two days per week for sixteen weeks) and are assessed using the same criteria as for lab-based research projects. Far from being an easy option, UAS projects have proved to be highly demanding and, importantly, offer the students a true research experience. UAS projects oblige students to consider all aspects of experimental design, something that is often denied students assigned lab-based projects in which the experimental investigation is ongoing and the study design is fixed.

UAS projects have proved to be highly popular with more applications than we have capacity to accept. A promotional DVD for the UAS scheme is available to view online (http://www.uas.ac.uk/video.htm; Figure 1).

**Figure 1.** Screen shot of the UAS promotional DVD (filmed in Dec 2005) that is viewable online at http://www.uas.ac.uk/video.htm




According to figures provided on the UAS scheme website, there are now 142 Departments in 49 Universities running modules or units based on the UAS model.

## Exemplar 5

***Practical provision across the curriculum.***
***Nottingham Trent University, Biological Sciences degrees***

**Description:**

There is a very strong practical element to undergraduate degrees across the biosciences cluster, with all practical classes being delivered by a core academic member of the students' teaching team, with help from a second academic or discipline specific demonstrator. In years 1 and 2, students study six 20 credit point modules, each including 20-24 hours of practical work. In their final year, students take four 'taught' 20 credit point modules, each including 18 hours of practical work, and a 40 credit point Research Project module, in which students conduct approximately 20 days of independent, supervised practical work on a topic aligned with their particular interests. Nottingham Trent University strongly feel that it is worth investing staff time and energy in running a comprehensive range of practical classes, in order to develop their students' practical, vocational skills and therefore enhance their employability.

This practical work is entirely lab based on most biosciences degrees, but involves a combination of lab work and fieldwork on the Ecology and Environmental Management (EEM) pathway of BSc (Hons) Biological Sciences; this degree is discussed further below. EEM practical work allows students to develop vocational skills such as surveying and sampling in multiple environments, using professional equipment and taxonomic keys to identify organisms in the field and lab. In addition, EEM students take one year 2 module and one final year module that deviate from the described format and are delivered during a week-long residential field courses including daily fieldtrips to study a diverse range of habitat types (coastal, freshwater, woodland). They also ask people external to the university to join us for guest lectures and/or on field trips, to increase the breath of our students' experience and open their eyes to the range of careers they will be equipped to pursue. As an example, students on the module Aquatic Ecosystems have recently had a guest lecture / seminar from an Australian researcher employed by a Research Institute in France, and these students will soon be heading into the field to study biomonitoring with an Environment Agency ecologist. Other field lectures are provided by employees at places we visit, for example considering primate behaviour at Twycross Zoo and sustainable farming at the Loddington Estate.

**Benefits:**

Evidence of the practical and vocational relevance of the degree BSc (Hons) Biological Sciences (Ecology and Environmental Management) comes from our graduate destinations: of the cohort graduating in 2013, one quickly secured employment as a freshwater ecologist with the Environment Agency and has recently moved to a full-time, permanent graduate-level position in a local ecological consultancy; one returned to his placement provider to take up a full-time position conducting agricultural research; and two remained in education (one MSc and one PhD) in the environmental sector; many others have entered graduate-level positions outside of biosciences. In addition, students are successful in securing yearlong placements during their third year: currently, EEM students are on placement with environmental consultancies, Nottinghamshire County Council, and one is conducting primate conservation work in a Thai forest. Such placements are supported by a dedicated, School-wide Placements Team, a Biosciences Employability Coordinator, and by individual academics, who provide support ranging from CV checking to arrangement of new, discipline-specific placements. The recent accreditation of the EEM degree by the Chartered Institute of Ecology and Environmental Management, provides further recognition of the vocational relevance of the degree, which we hope will further enhance graduates' job prospects.

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Society of Biology

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