TECHNICIAN ROLES, SKILLS, AND TRAINING IN INDUSTRIAL BIOTECHNOLOGY: AN ANALYSIS

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EXECUTIVE SUMMARY

1. This report investigates the roles, skills and training of technicians who work in the field of 'industrial biotechnology' (IB). The goal of the research described is to inform policy by examining how technicians are used by IB organisations, and how those technician roles are filled. Technicians are highly productive people who apply proven techniques and procedures to the solution of practical problems. They carry supervisory or technical responsibility and competently deliver their skills and creativity in the fields of science, engineering and technology. As the term 'technician' is currently used by policymakers in the UK, it denotes people occupying technical roles that require either Level 3 or Level 4/5 skills (that is, intermediate-level skills). Consequently, 'technicians' include both those individuals in 'skilled trades' and also 'associate professional/technical' roles.

2. This project is part of a wider research programme into technician duties, skills and training in various strategically important sectors of the economy, including the aerospace, cell therapy, chemical, composites, and space industries. Many of the major issues identified in this study, such as the challenges associated with employing over-qualified graduates in technician roles, align with those identified in studies of other industries.

3. IB involves the use of biological substances, systems and processes to produce materials, chemicals and energy. The processes and technologies in question can be utilised in a variety of different sectors, including pharmaceuticals, energy, food, chemicals, and waste management (European Commission 2011). The economic activity to which this use of biological resources and processes gives rise is known as the 'bioeconomy' and is estimated to add just under £1 billion of gross value to the United Kingdom's economy, with considerable potential for growth over the next 10 years.

4. Against this background, the research project reported here examined five broad sets of questions:

    - First, how many technicians are there in the field of industrial biotechnology?
    - Second, in what roles are technicians employed in industrial biotechnology? What are their main duties? What levels and kinds of skill and qualification do those technicians need?
    - Third, how do employers in industrial biotechnology fill technician roles?
    - Fourth, are organisations in industrial biotechnology suffering any skill shortages at the technician level?
    - Fifth, what – if anything – can be done to help employers in industrial biotechnology in their efforts to acquire skilled technicians?

5. Data were collected via interviews with 13 sector-level organisations, including government departments, learned societies, trade bodies, and sector skills councils, and through case studies of 30 employers. The employers in question included organisations whose principal activities were research and development (12 cases), process development (nine cases), and manufacturing (nine cases).

6. The share of technician roles in the workforce is smallest in those organisations principally involved in Research and Development (R&D), where technician roles amount to around 5% of the total workforce. The principal reason is that the duties associated with most of the science-related roles in such organisations require people to have at least an undergraduate degree. Technician roles account for a greater proportion – just under 20% – of the workforce in organisations specialising in process development. Those organisations carry out enough manufacturing in their pilot plants and process development laboratories for it to be worthwhile employing specialist manufacturing technicians, whose presence increases the share of technician roles in the workforce. The proportion of technician roles is greatest in the manufacturers visited for this study, where technicians comprise 25% of the workforce.
7. As the use of IB develops and matures, and more organisations increase both the scope of their activities from R&D to process development and ultimately to full-scale manufacturing, and also the scale of those activities, there will be more work of the kind carried out by specialist technicians needing to be done. This will make it worthwhile for more employers to create specialist technician roles as they develop a more elaborate division of labour within their organisations. Consequently, one would expect both the absolute number and the share of technician roles in the IB workforce to increase.
8. The main roles filled by the technicians in IB are as follows: laboratory and quality control technician; engineering maintenance technician; and manufacturing technician.
9. The most common technician role, in the sense that it is the role found in the greatest number of employers visited for this research project, was that of a laboratory and quality control technician. These technicians typically prepare the equipment and materials used in the practical scientific work carried out in their laboratory, and also carry out various kinds of experiment and scientific test. Such roles are most common amongst established manufacturers, which are of a sufficient scale for there to be enough work to justify the creation of specialist laboratory technician positions.
10. Some process development organisations, and in particular some R&D organisations, do not have dedicated laboratory technician roles. Some have outsourced the work in question. Others are currently small and therefore do not have the volume of work required to justify employing a specialist laboratory technician. However, there is a third group of employers that, although big enough to justify the creation of dedicated technician roles, still have their research scientists undertake relatively mundane work of a kind that could be done just as well by a technician (and, indeed, in some cases is done by technicians in other divisions of the same organisation located elsewhere in Europe).
11. Significantly, some employers that would previously have fallen into this third category have recently sought to create a more elaborate division of labour within their organisations by creating specialist laboratory technician roles. The rationale for doing so is that using specialist laboratory technicians to carry out routine tasks will free up more highly qualified workers to do more intellectual, problem-solving work, which employers say will increase both efficiency (reducing costs) and graduate satisfaction.

12. Yet even where there exist genuine laboratory technician roles that could be filled by people with intermediate-level qualifications, in practice they are more often than not filled by graduates. This phenomenon is known as 'over-qualification'; the highest level of formal qualifications possessed by the workers in question exceeds the level required to carry out their job effectively. The abundant supply of graduates from British universities means that they can be hired at relatively low wages, and without the firms having to incur the costs of training technicians themselves.

13. Although using graduates to fill technician roles brings short-term benefits in the form of cheap labour, it also gives rise to two problems. First, in the short run, while the graduates in question possess considerable theoretical knowledge, they often lack the practical ability to apply their skills effectively in the workplace. Second, and in the longer run, these graduates often become dissatisfied, partly because they are not stretched intellectually by the mundane, routine, and repetitive tasks they have to carry out, and also because of the relatively low wages they earn in these roles. Consequently, they often leave their employer relatively quickly, leading to a need to recruit new staff (which is especially frustrating if firms have spent time and effort improving their practical skills). These problems have led several organisations to begin to train apprentices to fill laboratory technician roles.

14. Maintenance technicians are employed by several of the larger manufacturing and process development organisations. Maintenance technicians – who tend to fall into three broad categories, namely mechanical, electrical, and control and instrumentation – carry out routine preventative maintenance and also breakdown and repair work on the relevant systems. Maintenance technicians in established manufacturing facilities typically possess Level 3 skills. In the case of the process development facilities, a higher level of qualification, typically a Higher National Certificate (HNC), is expected. The reason is that the technicians who work in process development facilities are working on novel kinds of plant, which they also often have to reconfigure to suit the particular process or product being developed.

15. The vast majority of manufacturers and process development organisations employ specialist manufacturing technicians, whose duties centre on operating the systems and equipment involved in production. In the case of some of the organisations that make various kinds of medicine or are engaged in bio-refining, the manufacturing process involves the use of something like a large-scale industrial plant. In this case, the manufacturing technicians will be the people who operate equipment on the plant. Second, there are those organisations where manufacturing involves the use of relatively small laboratory or cleanroom-based fermentation in order to make the product in question. In such cases, the manufacturing technicians will prepare and operate the bioreactors in which production takes place (according to standard operating procedures).

16. The broad subject area in which manufacturing technicians are qualified appears to depend on which of these two broad kinds of manufacturing process is being used. In the first case, where manufacturers use a large-scale industrial plant, manufacturing technicians tend to be qualified in subjects such as chemical process operations or manufacturing. In contrast, those organisations that manufacture in laboratory and/or cleanroom-type environments tend to employ as manufacturing technicians people who are qualified in subjects

such as applied science or applied biotechnology, with more of an emphasis on laboratory rather than process operations/engineering skills.

17. There also appears to be reasonably systematic variation in the precise level of skills and knowledge required of the manufacturing technicians. In the case of those manufacturers that primarily produce just one product using a well-established method of production, the manufacturing technicians or process operators tend to be qualified to Level 3. In the case of most of the process development firms, and also in the case of two of the manufacturers who specialise in contract manufacturing, however, even rank-and-file manufacturing technicians tend to be qualified to Level 4/5 (i.e. to possess an HNC, HND or Foundation Degree). In such cases the manufacturing technicians will not simply be carrying out a single, routine production process. Instead, they will be required to put into practice a variety of novel, and sometimes experimental, processes, depending on the particular technology that is being developed or on the particular kind of product currently being made.

18. There was a consensus amongst interviewees, in particular those from manufacturers using large industrial plants, that it would be easier to obtain manufacturing technicians for IB by converting process operators from the chemical industry, rather than by taking people with the relevant biological knowledge and equipping them with the relevant skills in process engineering. Experienced chemical process operators would already be familiar with many of the broad features of the large-scale manufacturing processes required for IB plants, and would therefore require less training than people who were familiar with biological science but not with engineering and process operations. Experienced chemical process operators are also more likely to be familiar with, and amenable to, the shift work required of manufacturing technicians in IB.

19. Employers have used a variety of strategies to fill technician roles *in the past:*

- In the case of laboratory and quality control technicians, the supply of relatively cheap biological science graduates has encouraged organisations to rely mainly upon over-qualified graduates rather than vocationally-educated technicians to fill such roles.
- Organisations have tended to use of a mixture of recruitment and apprenticeship training in order to obtain maintenance engineering technicians. Apprenticeship training is especially important in the case of control and instrumentation engineers, who are very hard to recruit ready-made.
- It is also hard to recruit experienced IB manufacturing technicians, simply because IB is a relatively new industry, so there has not been time to develop a pool of workers who have learned their trade in it.

20. The most common response to the limited availability of experienced manufacturing technicians in the past has been for organisations to rely on a 'recruitment-and-top-up-training' approach. This involves hiring people who have already received significant levels of education and training outside of IB and giving them the additional ('top-up') training so that they have the specific skills and knowledge required. Only a minority of organisations in this research had acquired some of their current manufacturing technicians via apprenticeship training.

21. The deficient practical skills and limited loyalty of graduates has begun to lead to an increasing interest in apprenticeship training to fill laboratory and quality control technician positions, with no fewer than seven of the organisations visited for this study recently beginning to train their own laboratory technicians (in addition to three that had used apprenticeships to fill such roles in the past).

22. Of the ten organisations that employed engineering maintenance technicians, half train apprentices. This trend looks set to continue, especially in the case of control and instrumentation engineers.

23. Employers expect to continue to find it difficult to recruit experienced, IB-ready manufacturing technicians. Consequently, employers will have to engage in some form of training to fill such roles. Accordingly, the number of organisations training apprentice manufacturing technicians has increased.

24. Some organisations that are currently taking apprentice manufacturing technicians, or are thinking seriously about doing so, have found it difficult to find a local college or university willing to offer the off-the-job course through which apprentices acquire the technical knowledge to underpin their practical skills. The principal reason lies in what might be called 'the tyranny of small numbers', namely the problem that the total number of students wanting to take the courses in question in the relevant geographical area is insufficient to make it worthwhile for the relevant providers to offer them.

25. To overcome these problems, ways need to be found both to aggregate the demand for training, so that the number of trainees breaches the threshold required to make offering training worthwhile for providers, and also to reduce the risk faced by potential providers. One way of doing so is to share as much IB technician training as possible with that for other process- and science-based industries.

26. Ways of ensuring that there is sufficient demand to entice providers into offering the IB-specific parts of the training include the following:

    - Develop only a small number of centres of excellence that offer the training, located in areas where there is a significant concentration of IB employers. Those centres should offer training via distance learning, supplemented by periodic residential courses or stints of block release, in order to extend their reach beyond the area in which they are located. The availability of such distance learning options need to be widely publicised.
    - At least some of the relevant training courses should be developed so as to 'double up' as CPD modules for more established workers, further increasing demand.
    - One way of reducing the risk faced by potential training providers is to utilise existing facilities, which are also used for purposes other than training (for instance, process development organisations such as Catapult centres). This will help to reduce both the size, and the riskiness, of the investment required to set up a training programme. Another advantage of using such facilities as the locus for training is that doing so should also help to ensure that training programmes and syllabuses are kept up to date and thereby remain attuned to the needs of industry.

27. Another important consideration is the so-called apprenticeship levy, which was announced in November 2015. The levy will involve the government imposing a payroll tax of 0.5% on employers with a wage bill in excess of £3 million, with the funding being used to create a National Apprenticeship Fund intended to subsidise those employers who train apprentices. If the implementation of this scheme leads to an increase in the number of genuine (Level 3+) apprentices being trained, then it should also help to alleviate the problem of the 'tyranny of small numbers', simply because there will be more apprentices needing training, both now and in the future, thereby making it more worthwhile for providers such as FE colleges to incur the fixed costs of making the relevant investment in tutors, workshops, and so on.

SECTION 1 INTRODUCTION

The government elected in 2015, like its Coalition predecessor and indeed the Labour party, is committed to rebalancing the British economy away from financial services and towards manufacturing (HM Treasury and the Department of Business, Innovation & Skills 2010, 2011; Adonis 2014a; Sainsbury 2014). The scope for such rebalancing to occur is of course influenced by many factors, including: the broad macroeconomic context, both domestically and globally within which British firms have to operate; the prevailing system of corporate governance under which industry in particular has to operate; and the availability of finance. Another other important factor, which will be the focus of attention in the project proposed here, concerns the availability of skilled workers, in particular – in the case of manufacturing – at the technician level.

Technicians are workers who apply proven techniques and procedures to the solution of practical problems. They carry supervisory or technical responsibility and competently deliver their skills and creativity in the fields of science, engineering and technology. As the term 'technician' is currently used by policy-makers in the UK, it denotes people occupying technical roles that require 'intermediate' – that is, Level 3 or Level 4/5 – STEM (science, technology, engineering and mathematics) skills. Consequently, the category encompasses both 'skilled trades' and also 'associate professional/technical' roles (Jagger *et al*. 2010).

The availability of a sufficient supply of technicians is arguably critical for facilitating the desired growth in manufacturing industry. The reason, as expressed in one report on technicians, is simple: "the level and type of skills that technicians have are vital to emerging markets in the UK, such as [the] advanced manufacturing and engineering industries. Becoming more production- and export-led means becoming more technician-led" (Skills Commission 2011: 16). However, policy-makers have expressed concerns about ongoing skills shortages at the technician level in the UK economy, and there is evidence that firms' efforts to expand are being hampered in a number of sectors by a shortage of skilled technicians (UKCES 2014: 6, 19, 2015: 7, 60-61, 67-68, 71; HM Treasury and Department of Business, Innovation & Skills 2011: 85; Spilsbury and Garrett 2011; Lewis 2012a, 2102b, 2013a, 2013b; Adonis 2014b: 6-9; Department for Business, Innovation & Skills and Department for Education 2015: 8; HM Government 2015a: 5). The government's acceptance of many of the recommendations of the Richard Review of Apprenticeships, and its decision to impose an apprenticeship levy, have been motivated by a desire to respond to these problems by increasing both the demand for, and supply of, high-quality apprenticeship training places with a view, ultimately, of increasing the number of qualified technicians in the UK economy (Richard 2012; BIS 2013; UKCES 2014: 14-15, 19; Department for Business, Innovation & Skills and Department for Education 2015: 3; HM Government 2015a: 9).

Policies that succeed in increasing the number and status of technicians will be developed only if the nature of technician work, and the demand for and supply of technician skills, are well understood. The research reported in this paper helps to achieve such an understanding by investigating the duties, skills, and training of the technicians employed in an important, emerging sector of the economy, namely industrial biotechnology. Industrial biotechnology involves the use of biological substances, systems and processes to produce materials, chemicals and energy

(IBIGT 2009; Capital Economics 2015). Defined thus, industrial biotechnology is not a discrete sector of the economy. Rather, it consists of a set of underlying, cross-disciplinary, enabling processes and technologies that can be utilised in a variety of different sectors, including – to name but a few – (bio-)pharmaceuticals, energy, food, chemicals, and waste management (European Commission 2011). For instance, the technologies and processes developed within industrial biotechnology can be deployed in the pharmaceutical sector to make drugs, in the energy and waste management sectors to make fuels such as bio-ethanol, in the agricultural sector to make agri-chemicals, and in the chemical sector to make bioplastics, industrial enzymes, and speciality chemicals. In this way, industrial biotechnology promises to create new opportunities for manufacturing across a wide range of industrial sectors. Moreover, thanks to its reliance on renewable inputs or 'feedstocks', including waste products from other industries, industrial biotechnology also has the potential to contribute significantly to the creation of an environmentally-sustainable, 'low-carbon' economy. The term 'bioeconomy' has been coined to refer to the economic activity that arises from using biological resources and processes to manufacture in this way (HM Government 2015b: 6, 11).

Industrial biotechnology is an important, emerging part of the British economy. It has long been seen as a high-growth, high value-added, knowledge-based part of the economy, possessing the capacity to attract inward investment and contribute to UK GDP growth (DTI 2003; BIS 2009; HM Government 2015b: 9, 13-15). Estimates of the size of the sector vary depending on precisely how it is defined and, therefore, on which organisations are thought to fall within it. One recent study indicates in 2013-14 there were around 225 companies making use of such processes and technologies in the United Kingdom, with a turnover of about £2.9 billion and employing around 8,800 people. Their activities are estimated to have added just under £1 billion of gross value to the United Kingdom's economy. This gives an impressive figure for gross value added (GVA) per worker of around £113,000 per annum. Growth potential appears to be good. Estimates indicate that the turnover of companies involved in industrial biotechnology has the potential to grow by 40% and 130% within the next five and ten years respectively, the latter figure equating to an annual growth rate for turnover of 8.8% in real terms (Capital Economics 2015).[1]

The significance of the choice of industrial biotechnology as the focus on the research reported here is threefold. First, while the rebalancing of the economy desired by policy-makers will of course require the growth of more established industries, such as automotive and aerospace, it will also depend upon the development of innovative technologies and products that can lead to the creation of new markets and new industries. Industrial biotechnology is a case in point, along with the space industry, nanotechnology, advanced materials and cell therapy (Willetts 2013). In considering industrial biotechnology, therefore, the report focuses on the very kind of emerging industry that must develop and flourish if UK manufacturing is to enjoy some sort of revival. Second, perhaps because until recently many firms in the industry were in the early stages of development, and so had not yet reached the point at which they engage in full-scale manufacturing, previous policy-related documents have tended to focus on issues relating to the supply of high-level skills, including doctoral training centres and MSc programmes (DTI 2003; IBIGT 2009; BIS 2009: 15-17). While there have been references to

1 For an alternative perspective, see TBR (2016: chapter 5).

the need to train operators and technicians for industrial biotechnology at least as far back as 2003 (DTI 2003: 95-96), and while similar observations have been repeated more recently (IBIGT 2009: 45; HM Government 2015b: 10, 24-26), the references to technicians contained in these documents are largely nugatory. This report aims to remedy that lacuna by considering the use made of technicians in industrial biotechnology, and their skills and training needs. Third, the development of new technologies and industries poses a distinctive challenge for those seeking to ensure that there is an adequate supply of technician skills. The challenge arises from the fact that that even if current curricula and apprenticeship training frameworks are up-to-date, they are likely to focus on established methods of production widely in use today, rather than on the emergent methods of production which will be used in the emerging industries that policy-makers are seeking to nurture. Therefore, even if there is a ready supply of experienced technicians from older, related industries, there is no guarantee that they will have the precise skills required for the new industry. Moreover, the time taken to train technicians to an adequate standard through apprenticeship programmes implies that if today's emerging industries are to have skilled workers in three to five years time, then it is necessary that they be trained now, in the emergent technologies they will be required to use once they have qualified. Hence the need for training frameworks, standards of competence, and actual training programmes that reflect future as well as current skills. So a consideration of industrial biotechnology raises interesting issues for those interested in increasing the number of apprentices and technicians in the UK economy.

The goal of the research described in this report is to inform efforts to ensure that employers in industrial biotechnology in the UK are able to acquire the skilled technicians they need, by examining how technicians are used and acquired. More specifically, the paper seeks to answer five sets of questions:

- First, what is the size of the technician workforce? Is it expanding, contracting or remaining stable?
- Second, in what roles are technicians employed in industrial biotechnology? What kinds and levels of skills and qualification do those technicians need?
- Third, how do employers in industrial biotechnology fill technician roles? Three sub-questions arise here. First, do employers use people with intermediate-level skills to fill those roles, or do they fill them by hiring over-qualified graduates? Second, to the extent that technician roles in biotechnology are occupied by people with intermediate-level skills and qualifications, do employers obtain those workers primarily by hiring experienced technicians from the external labour market or through some form of in-house training? Third, and, finally, to the extent that employers train people to fill technician roles, what does such training involve?
- Fourth, are organisations in industrial biotechnology suffering any skill shortages at the technician level?
- Fifth, what – if anything – can be done to help employers in industrial biotechnology in their efforts to acquire skilled technicians?

The structure of this report is as follows. Section 2 outlines the research methodology used in this study and describes the set of case study organisations. Section 3 begins the presentation of the study's findings, examining the current technician workforce with respect to four main sets of issues: the size of the technician workforce; the kind of roles that technicians fill; the skills – and, as a proxy for skills, the qualifications – they need to fill those roles successfully; and how in practice employers filled the technician roles currently found in their organisations. Section 4 continues with the presentation of the results, but shifts attention towards the strategies that employers in industrial biotechnology are currently using to develop their technician workforce. Section 5 considers the availability of training for industrial biotechnology, with a particular focus on apprenticeships, and considers various problems faced by employers who wish to make use of apprenticeship training, along with possible solutions. Section 6 summarises the discussion.

SECTION 2 RESEARCH METHODOLOGY

In the absence of a large data set concerning the skills and training of technicians in industrial biotechnology, a case study method was adopted. This has the benefit of making it possible to explore employers' decisions how about to obtain and use technicians in considerable contextualised detail.

The process of data collection had two main stages. The first involved a series of 15 interviews with 22 representatives of 13 sector-level organisations, including government departments, trade associations, and sector skills councils (most notably Cogent, the sector skills council for the chemical, pharmaceutical, nuclear, life sciences, petroleum and polymer industries). These interviews, along with secondary sources such as reports and policy documents concerning the industrial biotechnology industry in the UK, and also attendance at two major industrial biotechnology conferences, were used both to acquire information about key issues associated with the industry's use of technicians and also to inform the choice of case study organisations.

The second stage of the project involved the collection of data about technician duties, skills, recruitment, and training from a total of 30 current employers. Information was collected from them via 38 semi-structured interviews with a total of 45 interviewees, whose ranks included: owners; chief operation officers; HR, training and skills development managers; operations managers; technical and operations directors; chief technology officers and heads of technology; heads of R&D; and scientists. The interviews were carried out between January and October 2015. Notes were written up and, where gaps were revealed, these were filled by email follow-up where possible. Primary and secondary documentation was also collected where available.

The organisations in question were drawn both from the so-called 'IB core' – that is, from the set of organisations for whom the creation and supply of products and services that use industrial biotechnology is a major activity – and also from companies that adopt and utilise industrial biotechnology in order to develop their main manufacturing business (such as chemical production) (IBIGT 2009: 25-28). Industrial biotechnology encompasses a broad range of activities ranging from scientific research and development, through process- and technology-development work intended to facilitate the translation of ideas from research laboratories to commercial scale, to the use of developed processes and technologies in full-scale, commercial manufacturing. The organisations visited for this study varied according to which one of these three activities – R&D, process development, and manufacturing – is their current speciality. Moreover, in some cases, organisations were in the midst of expanding the scale and scope of their operations, moving in some cases from R&D to process development and, in others, from process development to full-scale manufacture.[2] The cases are summarised in Table 1.

2 In addition to the thirty organisations just mentioned, representatives of two firms that were planning to set up manufacturing operations in the UK, but which had not done so at the time of the interviews, were consulted.

Table 1: Summary of case study organisations

Type of organisation	Number of cases	Average number of employees	Average share of technician roles in the total workforce[a]
R&D	12	102	5%
Process Development	9	76	18%
Manufacturing	9	225	26%[b]

Notes
a: Technician roles may be filled by over-qualified graduates.
b: Based on data from seven manufacturers only.

The first, and largest, category of organisations comprises 12 firms that specialise in Research and Development (working at the laboratory level to develop new processes, technologies and products within the field of industrial biotechnology). Nine of the organisations are located in England, while the other three are elsewhere in the UK.

A second, slightly smaller group consists of nine organisations whose primary activity lies in process development (that is, in taking processes and technologies which have already been developed in the laboratory and examining whether, and if so how, they can be translated into larger-scale, commercial activities). Some of these organisations are carrying out this process development work on their own behalf, working on 'scaling-up' activities developed in their own R&D departments. In other cases, however, they are assisting with the commercial development and scale-up of ideas developed by other organisations. Seven of these organisations are based in England, whilst two are located elsewhere in the United Kingdom.

The final group of organisations was comprised of nine manufacturers. These organisations manufacture at commercial scale, their outputs including agricultural products, biofuels, biopharmaceuticals, enzymes, and speciality chemicals. Two of the nine organisations are contract manufacturers, making products on behalf of other companies. As was the case with process development, seven of these organisations are located in England, with two being situated elsewhere within the United Kingdom.

The profile of case study organisations arguably reflects the fact that industrial biotechnology is an 'emerging' technology, many aspects and applications of which are still under development. Consequently, many of the organisations involved in industrial biotechnology are still involved in fundamental research and process development, rather than full-scale manufacturing. That having been said, as we shall see, several of the organisations visited for this study are themselves in the process of expanding the scale and scope of their activities, making the transition either from R&D to process development or from process development to full-scale manufacturing. As we shall also see, this has important implications for the use those organisations make of technicians.

SECTION 3 VARIETIES OF TECHNICIAN ROLE AND ASSOCIATED DUTIES AND QUALIFICATIONS

This section of the report outlines what the research carried out for this project reveals about issues such as: the size of the technician workforce; the types of technician roles that are typically found in organisations in industrial biotechnology and the kinds of duties associated with those roles; the kind (level, and subject-matter) of qualifications those technicians typically possess; and how organisations working in the field of industrial biotechnology have gone about satisfying their need for technicians, focusing in particular on the balance they have struck between recruitment and (various forms of) training as a means of acquiring the technicians they need.

3.1 TECHNICIAN NUMBERS

Twenty-eight of the case study organisations provided usable data on the overall size of their technician workforce, the exceptions being two of the larger of the manufacturers, which supplied data on the overall size of their workforce but not on the number of technician roles in their organisations (see Table 1).

Consider first the 12 organisations whose principal activity is Research and Development. As discussed in more detail below, these organisations all reported that the duties associated with the vast majority of STEM roles in their organisations require people to be qualified to degree level or higher. The upshot is that seven of these organisations currently have no technician roles (although, as mentioned below, two of the smaller organisations noted that they are planning to create specialist manufacturing technician roles in their non-pilot plants). The remaining five organisations all have relatively small numbers of laboratory technicians, typically amounting to less than 10% of their workforce. Across the entire set of R&D organisations, therefore, technician roles account for no more than around 5% of the workforce. Moreover, as we shall see, these roles are often filled, not by people with intermediate-level qualifications, but by over-qualified graduates.

The share of technician roles in the workforce is higher in those organisations involved in process development. The figures reported by interviewees indicated that roughly one-fifth of their workforce occupy technician roles. The higher share of technician roles in the workforce is due principally to the fact that these organisations carry out enough manufacturing activity in their pilot plants and fermentation process development laboratories for it to be worthwhile employing specialist manufacturing technicians. And it is the presence of those manufacturing technician roles that raises the share of technician roles in the workforce above the very low level seen in R&D organisations.

The proportion of technician roles in the workforce is, unsurprisingly, greatest in the case of the manufacturers visited for this study, accounting for around one quarter of the workforce. If anything, this figure is likely to underestimate the share of technicians, the reason being that two of the best-established manufacturers, in which the share of technicians in the workforce is likely to be greatest, were unable to supply data on the number of technicians they employ.

It is also well worth observing that, as the industry develops, and more firms increase the scale of their activities from R&D to process development and ultimately to full-scale manufacturing, one would expect the share of technician roles in the industrial biotechnology workforce to increase. Thirteen of the 30 organisations visited for this study – four R&D organisations, six process developers, and three manufacturers reported that they are either expanding, or planning to expand. As described below, in the case of two of the R&D firms and two of the process developers, this expansion will facilitate a more elaborate division of labour within the organisations, which will create specialist technician roles for the first time (sometimes laboratory technician roles, sometimes manufacturing technicians). As the interviewee from one organisation that has just begun large-scale manufacturing put it, that change will "create a lot of repetitive jobs" for which technician-level skills rather than graduate-levels skills will be appropriate. Similar views were expressed by a senior manager from another organisation that has just become big enough to warrant employing specialist technicians, according to whom, "lots of skill and value will be delivered to the company by technicians who can get in there and get the job done", whilst freeing up people with degrees and PhDs for higher-level work. The other expanding organisations already have technician roles but plan to create more.[3] This suggests that both the absolute number of technician roles, and also their share in total employment, is set to increase.[4]

3.2 TYPES OF TECHNICIAN ROLE

A number of different types of technician work within the organisations involved in industrial biotechnology. In what follows, a range of typical technician roles will be described in order to provide the reader with a sense of the kinds of duties undertaken by those technicians.

3.2.1 Laboratory/quality control technicians

Specialist laboratory and quality control technician roles, requiring Level 3-5 skills, were found in 21 of the 30 organisations visited for this study. We consider first the question of what duties the occupants of these roles carry out, before examining, second, how common these roles are in different kinds of organisation, and, third, who fills them.

3.2.1.1 The duties of laboratory and quality control technicians

The tasks undertaken by such technicians will, of course, vary somewhat depending on the particular kind of organisations for which they work. But their duties typically fall into two categories: the first involves preparing the equipment and materials used in the practical scientific work carried out in their laboratory; the second requires technicians to carry out various kinds of experiment and scientific test.

The preparatory activities, all of which will be done in line with standard procedures set out by more senior staff, may include: maintaining the cleanliness of the laboratory to appropriate standards; ensuring, and documenting compliance with, health and safety regulations; ensuring that there are appropriate stocks of chemicals, reagents, glassware, buffers and solvents; preparing micro-biological media and analytical standards; calibrating, and/or checking the calibration of,

3 In addition, the CEOs of two other firms interviewed for this project indicated that they are planning to set up manufacturing facilities in the UK, for which they will need manufacturing, laboratory and maintenance technicians.

4 Also see TBR (2016: 46, 49). For similar findings in the case of the Australian biotechnology industry, see Beddie *et al.* (2014: 38).

equipment; ensuring that other laboratory equipment is appropriately maintained and sterilised; and carrying out the safe disposal of laboratory waste.

In the case of the experiments and tests, the laboratory technicians may be involved in collecting and preparing samples for testing (e.g. by taking samples from a manufacturing plant, or by using swabs, contact plates and active air samplers to test for the presence of contaminants in cleanrooms). The sampling will often need to be done aseptically (i.e. so as to avoid contaminating the sample or wider production process with microbes, etc.). The technicians typically also carry out some of the (relatively simple) tests themselves, in line with standardised procedures. The tests in question will depend on the type of organisation employing the technician, but may include:

- tests (e.g. assays, pH testing) designed to assess the properties of samples taken from raw materials, from intermediate stages of the production process, and also from batches of the final product; and
- environmental monitoring tests, designed to check for the presence of various kinds of contaminant (e.g. microbes, particulates) (especially in the case of those organisations that use cleanroom facilities).

The methods of testing will vary according to context. Examples include: high-performance liquid chromatography (HPLC) and gas chromatography (GC); and plating and counting bacteria. Laboratory technicians will typically document the results in accordance with established procedures (e.g. GMP) so that they are available either for quality control purposes (e.g. in the case of manufacturing plants) and/or for interpretation and analysis by more senior colleagues (e.g. in the case of R&D and process development facilities). By providing such raw data, technicians play an important role in facilitating the work of the scientists and engineers whom they support (Barley and Bechky 1994: 88-92, 115-16; Lewis and Gospel 2011: 16-20).[5]

Rank-and-file laboratory and quality control technicians typically require Level 3 skills and knowledge to carry out their duties. However, as we shall see in Section 3.2.1.3 below, in practice such roles are often filled by people who possess much higher levels of formal qualification.

3.2.1.2 The incidence of laboratory and quality control technicians in different kinds of organisation

Perhaps unsurprisingly, such roles were most common amongst the established manufacturers visited for the study, being found in eight of the nine organisations in question.[6] All of these organisations had reached a sufficient scale for there to be enough work to justify the creation of a specialist laboratory technician or quality control role. The behaviour of these organisations exemplifies one of the oldest insights in economics, whose origins can be traced back at least as far as Adam Smith, namely that as the scale of an organisation's activities increases, the scope for the specialisation through the creation of roles dedicated to particular parts of the production process also grows.

5 The interested reader can see how these descriptions of the duties normally carried out by laboratory technicians compare with the more abstract statement of the competences a qualified laboratory technician working in one of the life and industrial sciences by examining the relevant Trailblazer standard, which is reproduced as Appendix 1 of this report.

6 The ninth firm did not employ laboratory technicians simply because it outsourced the kind of work carried out elsewhere by laboratory technicians.

Seven of the nine process development organisations have specialist laboratory technicians, as do five out of the 12 R&D organisations. In the two process development organisations that do not have specialist laboratory technicians, the kinds of tasks they might carry out are undertaken instead by research scientists, simply because there is insufficient work to make it worthwhile employing a specialist laboratory technician. One of two process development organisations in question does employ technicians, but they are process technicians charged with the task of running its pilot plant rather than laboratory technicians. The other organisation also argued that it was reluctant to employ specialist laboratory technicians because, given its current scale, all of the laboratory staff were engaged in report writing for, and making presentations to, clients; these were duties that, it was felt, required people to have at least a first degree.

One of the five R&D organisations, and one of the process development firms, which have specialist laboratory technician roles have created those positions only recently. The reason is that they were looking to create a more elaborate division of labour within their organisations, whereby graduates would be released from relatively mundane tasks to focus on higher-level, analytical tasks by the creation of specialist technician roles. In the words of one interviewee, once it reaches a certain size a modern-day laboratory is "like a production facility" in the sense that a lot of the work involves "doing standardised experiments and procedures." Those activities can be carried out by people with sub-degree level qualifications because "the method is already set up for them [via standard operating procedures] … It's like following a recipe [so] you don't need a degree." As the head of another laboratory put it, "PhDs get the process sorted out [i.e. specified], the technicians will keep the established processes running." Interviewees thought that a more elaborate division of labour along these lines would both increase graduate satisfaction and also, it was thought, save money so that, in the words of one interviewee, the creation of such roles is "driven by a commercial imperative." A third company, from the R&D sector, is also thinking of developing a more elaborate division of labour, for similar reasons, namely that having a specialist laboratory technician to carry out routine duties would make it possible to "release scientists to do more intellectual, problem-solving work." [7]

Some of the seven R&D organisations that do not currently have specialist laboratory technician roles maintained that the vast majority of the work they undertake requires people to have at least degree-level skills and knowledge. The remaining lower-level work is either outsourced or simply carried out by more highly-qualified people as part of their role (especially in smaller organisations, where the volume of support work is deemed too small to warrant the creation of a specialist technician role).[8] Two of the seven also noted that their scientists liked to "see jobs through from start to finish" and were therefore reluctant to hand over responsibility even for relatively mundane tasks to technicians. In those organisations, in other words, research staff are reluctant to permit a more elaborate division of labour.[9] However, interviewees from two R&D organisations that do not currently use specialist laboratory technicians observed that other parts of the same company which were doing the same kind of work

7 For a similar example involving a contract research analysis laboratory drawn from the chemical industry, see Lewis (2013a: 18).

8 A small number of small organisations noted that they had undergraduate interns do mundane, preparatory work of the kind that might otherwise be done by a laboratory technician.

9 For an analogous finding from the space industry, see Lewis (2012a: 13, n. 6).

but were located elsewhere in Europe did have genuine technician roles, filled not by graduates but by people who had been educated via apprenticeships. The occupants of these roles, the interviewees said, often do "quite high-level technical work". This suggests that the nature of the work being undertaken in R&D organisations is not always the key reason for the absence of technician roles. Perhaps unsurprisingly, the two countries mentioned by the interviewees were Austria and Switzerland, so-called 'dual system' countries where the apprenticeship route is well-established and viewed as a high-status alternative to university education (Steedman 2010).

3.2.1.3 How are laboratory and quality control technician roles filled?

While the duties associated with laboratory and quality control positions can be discharged by people with intermediate-level qualifications, the evidence suggests that in practice such roles are often filled by people who are qualified to degree level or above. Of the 21 organisations that have such roles, 13 reported that some or all of them are filled by graduates. This is an example of what is known as over-qualification; the highest level of formal qualifications possessed by the workers in question exceeds the level required to carry out their job effectively (Wolf 2011: 29). In the words of one interviewee, "Lots of quality control roles are filled by graduates who are over-qualified for the work they do."

This "surfeit of graduates and PhDs in biotech", as another interviewee described it, arguably reflects the impact of the considerable expansion of higher education in the UK over the past two decades. One consequence of the increase in the number of graduates being produced is that employers have been tempted to take on graduates to fill positions that would previously have occupied by people qualified to below degree level. This is not because the level of skills required to fill the role has increased, but rather because employers were not required to incur the costs of training the graduates in question (whereas the costs borne by employers who train technicians to fill such positions are substantial). In the words of Alison Wolf:

> *Higher education subsidies mean that employers are often able to displace a sizeable part of the training they used to do on to higher education institutions. Even if the training is less specific to their needs, and even without the work the apprentice does, they are often at least as well off as under apprenticeship, if not better off … [so] employers will inevitably recruit as far as possible from graduates (2009: 96; also see Mason 2012: 15-19, 27; Keep and James 2011: 59-60; Wolf 2015a: 73-74).*[10]

The abundant supply of graduates means that they can be hired at relatively low wages, and without the firms having to incur the costs of apprenticeship training. As a senior manager of one firm put it, "If there's a load of graduates looking for jobs, so supply is high, why not take them? They're cheap, the supply's there … [and] you don't need to give them day release … [so] firms can get lazy and just recruit graduates." In a similar vein, another interviewee commented that, "There are too many graduates … and we just don't have enough graduate jobs for them." All told, no fewer than 13 of the firms that have specialist laboratory and quality control technician roles reported that advertisements for such posts lead to a plethora

10 Evidence indicates that the problem of over-qualification is significant both in absolute terms, with somewhere in the region of one-quarter and one-third of UK employees falling into that category (Chevalier and Lindley 2009; Green and Zhou 2010; UKCES 2015: 7, 57), and also that the scale of the problem is worse in the UK than in most other European nations (Holmes and Mayhew 2015: 25-28).

of applications from people qualified to degree level or above. And this supply of relatively cheap graduate labour has encouraged firms to rely on graduates rather than vocationally-educated technicians to fill skilled trades and associate professional roles.

In the context of these discussions about using over-qualified graduates, and the possibility of doing so, several employers also spoke about the current status of technicians in the UK, arguing both that it had deteriorated over time and also that it compared unfavourably with the standing enjoyed by technicians in other countries. One interviewee argued that in the past, when he had worked in a large chemical company, technicians were respected: "They were the oil that made the machine [i.e. the organisation] run ... They had esteem." Now, however, with the current emphasis on getting a degree, matters were different: "I have encountered a lot of snobbery towards technicians in the past ten years … The term 'technician' seems almost dirty". Similar ideas were expressed by another interviewee, who remarked that, "There's a perception [amongst students, schools] that career paths aren't there [for technicians] and there is a need to have a degree to compete in the workplace." At root, the low status and esteem in which technicians are often held arguably reflects the fact that their work stands at the interface between manual and mental labour. The danger is that, if the more knowledge-related aspects are not acknowledged, then technicians' work is associated only with physical effort and is therefore accorded low status. Moreover, because their role is to support and facilitate the work of another, more 'eminent' occupation, which is also widely seen to exercise authority over them, technicians' contribution to research tends to remain invisible, with the result that technicians' standing is not commensurate with the true significance of their work (Shapin 1989; Barley and Bechky 1994, 91, 116).

Another interviewee, who had lamented both the practical skills and attitudes of graduates, commented that there was a need to bring back a work-based route which enabled people to acquire practical skills on the job, but that it would be important to ensure that people "did not dismiss it as third class" compared with more academic, university-based paths. Two interviewees mentioned the possibility of registration with professional bodies as a means of improving the status and standing of technicians, and of demonstrating to young people that there was a viable, respected career ladder up which someone who started with an apprenticeship could ascend.

Interviewees noted that the oft-witnessed reliance on graduates to fill technician roles is often a mixed blessing, bringing short-term benefits in the form of cheap labour but also giving rise to two kinds of problem in the long run. The first problem arises from the fact that the graduates in question often become dissatisfied with their lot, partly because they are not being stretched intellectually by the mundane, routine, and repetitive tasks they have to carry out, and also because of the relatively low wages they earn in such entry-level roles. The upshot is that "they quit [either] because they're looking for exciting, stretching, challenging work", as one operations manager put it, and/or because, in the words of one HR manager, "you risk losing them due to a low salary".[11] Eight firms mentioned this as a problem in the context of laboratory and quality control technician roles.

11 Such findings are consistent with the work of Green and Zhou (2010) who, using evidence drawn from national skills surveys, find that where over-qualification is associated with a genuine under-utilisation of the skills of graduates, as is the case with the laboratory technicians described in the main text, substantial job dissatisfaction results on the part of the employees.

In the words of one head of a research and development facility, over-qualified graduates "get de-motivated … [saying] 'I have a PhD and I get paid £20K.' It's not very motivating … We've had this problem time and again." Similar views were expressed by another interviewee, who commented that: "Graduates have the expectation they'll be promoted very quickly ... but it doesn't happen, they often get promoted only slowly" and, as a result, they become unhappy and often leave. Such problems were especially prevalent where the prospect of promotion from entry-level positions to more senior and demanding roles was limited, as is the case at most of the organisations in question.[12] On this view, while bringing short-run benefits, the strategy of using over-qualified graduates is: "it's not going to work out in the long run … You need them to stick around" and they won't, as they will not be satisfied with a tech level job and pay.

The second problem concerns the fact, mentioned by five of the employers in the case of their laboratory technicians, that while the graduates in question possess considerable theoretical knowledge they often lack the practical ability to apply their skills effectively in the workplace. One senior manager lamented the deficiencies in the practical skills of all-too-many graduates as follows: "Students are very well-educated in the theory but the practical skills are appalling … so you have to go through the basics again … They've wasted their time getting a degree because they can't problem-solve and can't do practical things … Standards in practical work aren't there." Five employers attributed graduates' lack of practical skills to the limited amount of practical work involved in undergraduate degrees. As the general manager of one R&D organisation put it, undergraduates are "taught fundamental theory but when it comes to practical applications they don't have the lab time and the hands-on practical experience … so they still need to get practically trained up." Similarly, one team leader in a process development organisation commented that graduates, even those drawn from good universities, "have barely used a pipette … You can employ graduates and they won't know how to set up experiments." Hence, while graduates are often over-qualified for technician roles in terms of the theoretical knowledge they possess, they may also be under-skilled because while they have high-level academic qualifications they lack the practical skills with which a more vocational route would have equipped them. We have here an example of what a recent study of over-qualification refers to as a "possibility which tends to get overlooked – that graduates are less capable in some occupations than the non-graduates they are displacing" (Holmes and Mayhew 2015: 12; also see UKCES 2015: 46). In such cases, the authors continue,

> *certain skills are more effectively produced in the workplace through supervised practice, rather than in an academic institution. However, given labour market and societal pressures and government rhetoric and information, the sort of able young person who might once have gone down a work-based vocational learning route (and successfully entered a good occupation) opts instead to apply to university, and consequently fewer new labour market entrants have those particular skills. (Holmes and Mayhew 2015: 12.)*

12 One manufacturer argued that while its degree-educated laboratory technicians may be over-qualified for the entry-level position they fill immediately upon joining the firm, a careful selection procedure, designed to identify those with good practical skills, coupled with early opportunities for increased responsibility and promotion, can help to avoid the problems mentioned in the main text.

The case of laboratory and quality control technician roles appears to be a case in point.[13]

The combination of these two problems – that is, of a lack of practical skills, which implies that graduates require on-the-job training in practical skills, and high labour turnover amongst graduates in technician-level roles – is especially frustrating for employers that, having spent time and effort equipping the graduates with the practical skills required for technician roles, then see them leave before the firm enjoys a return on its investment. If this happens, one interviewee commented, "you're back to square one and from the lab's point of view you need to train someone all over again." Another interviewee also lamented the high turnover amongst her support staff, commenting that their departure "is frustrating when you've just trained them up." Five firms mentioned problems of this kind in the case of their laboratory and quality control technicians.

As we shall discuss in more detail in Sections 3.3.1 and 4.2.2 below, several organisations have responded to the problems caused by unhappy, over-qualified graduates who are deficient in practical skills by beginning to train apprentices for their laboratory and quality control technician roles.

3.2.2 Maintenance technicians

Technicians of this kind are employed by six of the larger manufacturers and four of the process development organisations visited for this study. Three broad categories of maintenance technician are normally distinguished: mechanical; electrical; and control and instrumentation. We shall briefly outline the principal duties of each.

Mechanical maintenance technicians are responsible for planning and carrying out routine, preventative maintenance on the mechanical equipment and systems found in industrial plants (e.g. by oiling and lubricating machines, changing screws and bearings, and replacing seals and valves). They also diagnose and solve mechanical faults and breakdowns. This will involve them checking, maintaining and – where necessary – repairing a variety of mechanical equipment and parts, including pumps, fans, silos and tanks, valves, compressors, pipes, condensers, heat exchangers, fans, and various (other) kinds of hydraulic and pneumatic systems.

Electrical maintenance technicians will look after the electrical systems (power, lighting and fire alarm) and equipment (motors, pumps, agitators, compressors, etc.) in facilities. They will perform routine maintenance and testing, and will also carry out first-line fault-finding and repair work on wiring and equipment in the event of breakdowns. In addition, they will also carry out electrical isolations to facilitate mechanical maintenance. Like both of the other kinds of technician described here, electrical technicians will also be involved in the installation and commissioning of new plant. Also, as with the other two kinds of engineer, these technicians will in carrying out their duties comply with the required standards for documenting the work done (including, where appropriate, cGMP).[14]

13 For similar findings in the case of industrial biotechnology, see TBR (2016: 46). Similar problems arise both in the case of the laboratory technicians who work in the chemical industry and in contract analysis laboratories, and also in the case of teaching laboratory technicians who work in university chemistry and biological science departments (Lewis and Gospel 2011: 29, 65-66; Lewis 2013a: 16-18). An expression of the government's concern about the variable quality of practical training provided by biology degrees can be found in BIS (2011: 20).

14 The term 'cGMP' refers to 'current Good Manufacturing Practices'. These are the practices that the regulatory agencies controlling the authorisation and licensing of pharmaceutical products stipulate must be followed by pharmaceutical companies in order to ensure that the products being made are of high quality and do not pose any risk to the public.

Control and instrumentation maintenance technicians maintain and, where necessary, repair the instruments that form part of the distributed control system (DCS) through which many modern industrial plants are operated. The DCS consists at least in part of instruments that (i) measure key variables – such as pressures, temperatures, flow rates, weights, volumes, along with the properties of various liquids and gases – in different parts of the plant and then (ii) convert those measurements into electrical signals that are transmitted to the plant's control room. The responses from the control room, which come in either electrical or pneumatic form, signal to the process operators out on the plant how the appropriate variable needs to be altered. Control and instrumentation technicians ensure that the DCS system performs these tasks well. In addition to calibrating the instruments, control and instrumentation technicians will also maintain and, in the event of a breakdown, repair or replace them as appropriate.

Maintenance technicians in established manufacturing facilities typically possess Level 3 skills. In the case of the process development facilities, however, a higher level of qualification, typically an HNC, is expected. The reason is that the technicians who work in those facilities are not simply involved in the routine maintenance and repair of a standard, established plant. Rather, interviewees stated, the technicians will be working on pilot plant facilities, which – almost by definition – will be unfamiliar in some respects. A higher level of skills and knowledge is important first of all in helping technicians deal with such novel kinds of plant. In addition, the nature of the work carried out in such facilities implies that they be reconfigured far more often than an established manufacturing facility, depending on the particular kind of products and production processes being investigated at that time. The technicians will be required to carry out the work required to reconfigure the plant, and even to build bespoke parts in order to realise the new design. This, interviewees argued, required them to have a higher level of skills and knowledge than would normally be possessed by a maintenance technician, with a Level 4 qualification such as an HNC being the minimum needed.

Technicians may even have input into the design of parts of the newly configured pilot plant. The technicians' practical experience of how pieces of plant or equipment work, and of the problems which can arise in using that kit, can sometimes enable them to provide advice and feedback to ostensibly better qualified, but in terms of hands-on experience often less knowledgeable, graduates about how to design the plant so that it runs more effectively. As the manager of one pilot plant facility put it, when describing how technicians can help the scientists at the facility develop and test their ideas, "We say where the problem is, or what we want to do, and they'll come up with the ideas." What this goes to show is that there may be occasions when vocationally educated technicians are able to advise graduates occupying more senior positions within their organisation about how best to design or modify certain features of a pilot plant.[15]

Maintenance technicians who occupy more senior roles in manufacturing facilities – variously known as, for example, 'Lead Engineers', 'Assistant Engineers' or 'Maintenance Managers' – will also typically be more highly qualified, possessing HNCs or HNDs in engineering. They will be responsible for ensuring that the plant's systems are maintained in accordance with the relevant regulations and company policies and will inspect the plant, and manage and organise the work

15 Similar observations have been made in the case of technicians working in university engineering workshops (Lewis and Gospel 2011: 16-17), in aerospace (Lewis 2012b: 9-10), and in the chemical industry (Lewis 2013a: 14-15).

of the more junior technicians, in pursuit of that goal. In addition, they will also help junior colleagues with more difficult breakdowns. They will also carry out 'root cause' analysis by seeking not merely to diagnose the immediate cause of a breakdown but also to identify the underlying ('root') causes of recurrent technical problems. The additional technical knowledge provided by an HNC or HND enables them to do this. The occupants of such roles may also work in project management, liaising with graduate-level engineers in designing, installing, commissioning, and testing new equipment and modifications and improvements to the plant.[16]

3.2.3 Manufacturing/production technicians

3.2.3.1 The incidence of manufacturing technicians in different kinds of organisation
Manufacturing or production technician roles either are, or will shortly be, found in 18 of the 30 established case study organisations. The details are as follows:

- Eight of the nine established manufacturers either currently employ manufacturing technicians, or – in the case of an organisation that is in the process of scaling up its operations from R&D to full-scale production, plan to create such roles – in order actually to carry out production in their facilities.[17] The exception is a manufacturer that employs specialist operators to carry out production but which, because of the simple nature of its production process, requires them to be qualified only to Level 2. The roles in question therefore count as semi-skilled rather than technician roles.[18]
- Eight of the nine process development organisations either currently employ manufacturing technicians or, in the case of one organisation which is expanding and will soon have enough work to justify employing a specialist manufacturing technician, will shortly establish such a role. The one process development organisation that currently has no plans to employ specialist manufacturing technicians is relatively small and, because the workers who carry out its laboratory-based fermentations also have to write reports and make presentations to clients, prefers to rely on graduate-level scientists rather than to create a specialist technician role.
- Two of the R&D organisations are also planning to create specialist manufacturing technician roles. Both organisations are in the process of setting up pilot plants and wish to employ specialist process technicians to run their new facilities: one intends recruit a small number of technicians themselves; the other intends to outsource the task of obtaining its manufacturing technicians to a large chemical firm that is acting as the 'landlord' for its pilot plant.

16 The relevant Trailblazer standard, which sets out the competences required of a maintenance engineer employed in the life and industrial sciences, is reproduced as Appendix 2 of this report.

17 In addition, representatives of two more firms that currently do not operate in the UK, but which are planning to open up manufacturing facilities here, also intend to employ specialist manufacturing technicians.

18 Two of the other manufacturers employ some Level 2 operators. Overall, then, three of the eight manufacturers visited for this study stated that at least some of their production processes required rank-and-file operators to have only Level 2 skills, so that the workers in question are only semi-skilled workers rather than technicians. In these firms, some or all of the production processes require workers to do little more than measure out raw materials accurately, as set out in a set of work instructions, and then blend them together in a tank. Nothing more than basic numeracy and literacy, and attention to detail in following standard operating procedures, is required of the workers in question. For similar findings in the case of the process operators employed in some plants in the chemical industry, see Lewis (2013a: 9, 11-12).

3.2.3.2 The duties of manufacturing technicians

Manufacturing technicians will operate the systems and equipment involved in routine, day-to-day production operations. Their duties will typically involve them preparing, starting-up, operating, monitoring, controlling, and then closing down safely, the equipment used in manufacturing. They will do so in line with the standard operating procedures stipulated by their organisation; these are designed to ensure that the process is operating safely and efficiently, and that it will yield a product with the desired properties. Precisely what this involves will vary depending on the particular kind of production process utilised in the organisation for which they work. Two broad cases will be considered here.

First, in the case of those firms where manufacturing involves carrying out smaller-scale laboratory or cleanroom-based fermentation in order to make the product in question, then the manufacturing technicians will: prepare the bioreactors in which production takes place by configuring them in the right way for the particular process being undertaken; fill the reactors with the liquid medium in which the cells will be grown; add the cells; 'inoculate' the reactor by adding bacteria or yeast; feed the cells as they develop by adding glucose and nutrients; control the temperature, pH, dissolved oxygen levels, etc., in the reactor in order to ensure that the optimal conditions for cell growth are maintained; monitor the growth of the cells, for example by taking samples for laboratory analysis, to ensure that they are developing appropriately; extract the product; and clean (sterilise) the reactors so that they are ready for re-use. All of this will take place in accordance with standard operating procedures. Once the 'upstream' production work just described has been completed, (other) manufacturing technicians will also be involved in the so-called 'downstream' work involved in separating and purifying the output produced by the bioreactors (e.g. using chromatography, filtration and, in larger industrial plants, distillation columns) in order to ensure that the final product is obtained.[19]

Second, in the case of some of the organisations that make various kinds of medicine or that are engaged in bio-refining, the manufacturing process involves the use of something more like a large-scale industrial plant. In this case, the manufacturing technicians will be the people who operate equipment on the plant, again in accordance with standard operating procedures that (i) specify the ranges within which certain key parameters – concerning temperature, pressure, pH, oxygen levels, flow rates, etc. – must be maintained during production, as well as (ii) providing instructions setting out how the technician should respond if particular parameters either look as if they might move, or have moved, outside the prescribed range. These procedures might require the technician to: add material of some kind, such as nutrients or enzymes, to the vessels in which production takes place; start, shut down or otherwise change the speed or operation of equipment such as pumps and agitators; open or close valves; use instruments out on the plant to monitor the values of key parameters to make sure that the production process is taking place safely and efficiently; take samples for laboratory analysis to

19 Several interviewees argued that, while in practice manufacturing technicians might be divided into those carrying out upstream and downstream roles, it is important for all of them to have a good all-round knowledge of the process, including both its upstream and downstream dimensions. Interviewees mentioned two main reasons why they thought this was the case. First, having been proficient in both upstream and downstream activities makes the workforce more flexible. As one manager put it, "We want flexible, broadly-based people." Second, manufacturing technicians need to know what happens elsewhere in the process, both upstream and downstream of them, so that they understand how what they do to the process affects, and is affected by, the behaviour of those other people. Hence, in the words of one training manager, manufacturing technicians "need a wider view of the process" than can be had from specializing in either upstream or downstream roles.

ensure that the cells that lie at the heart of the production process are developing appropriately; prepare and isolate equipment for maintenance; and carry out routine safety checks around the plant.[20]

In addition, it is important to note that both in the case of laboratory- or cleanroom-based fermentations, and also where production is carried out in something more like a large-scale industrial plant, technicians will need to be able to: work in shifts; be proficient in carrying out procedures aseptically, so as to avoid contaminating the product being made; work in cleanrooms; maintain accurate production records, in a fashion consistent with both internal and external (e.g. cGMP) regulatory requirements; and participate in continuous improvement, so as to optimise the processes being used.

Several interviewees commented that, notwithstanding the use of standard operating procedures, there remains a need for manufacturing technicians to exercise judgment in carrying out their duties. Especially given the continuous nature of many of the production processes used in industrial biotechnology, which implies that production processes cannot easily be halted in mid-flow, technicians need to be able to respond appropriately to what is happening in real time. This may involve them changing some aspect of the production process themselves, along the lines noted above, or by recognising that the best response to the situation is to call on a more senior colleague.

Good technicians are able to do this, one facilities manager argued, because they have "important tacit knowledge". He elaborated on this point by noting that, just as there is a difference between someone who can read a cookery book and so have explicit knowledge of the recipes, and someone who in addition to having that explicit knowledge also has the tacit knowledge of how actually to carry out the instructions found in the recipes to good effect, so too there is a difference between manufacturing technicians who have explicit knowledge of the standard operating procedures and those who also have the tacit knowledge of what those procedures mean, and require to be done, in particular circumstances. Good technicians "have know-how, built up over years, often tacit, about how to get things done practically." They "notice things" such as, to take two simple examples mentioned by interviewees, how to add raw materials to a fermenter in order to minimise the generation of foam (too much of which can cause problems in the production process) and how to dilute solutions in order to make a process work. In addition, in the words of another interviewee, a good technician "knows when to panic and when not to" and is also a good judge of "when to leave alone and not interfere in the process [like not stirring a cake too much]." This kind of knowledge can only be acquired on the job, and often requires "several years experience" in the relevant role. As another interviewee noted, to gain this "tacit knowledge" you need "practical experience of the workplace … of the process, the technology, and of the critical aspects of the plant."[21]

20 Four of the manufacturers that use large-scale industrial plants either have trained, or are planning to train, their manufacturing technicians to do basic mechanical maintenance, both of the routine preventative kind and also simple fault-fixing. This is essentially for two main reasons: first, so that basic breakdown maintenance can be done without wasting time waiting for the maintenance team to arrive (which is especially important during night-time shifts, when specialist maintenance technicians are typically not on site); and, second, so that the specialist maintenance technicians can focus on more difficult problems that really require their specialist skills. For a similar trend in the chemical industry, see Lewis (2013a: 12-13).

21 The importance of such tacit knowledge also means that it is more difficult for foreign competitors to replicate the biological processes that underpin the manufacture of goods produced using industrial biotechnology, implying that any comparative advantage achieved in the production of such goods will be more resistant to erosion by foreign competition (DTI 2003: 87-89).

One important aspect of this tacit knowledge is the ability to solve basic problems with the production process when things go wrong. As the director of one process development facility put it, "Good technicians accurately identify that there is a problem and do first-line diagnostics." These views were echoed by the head of operations at a manufacturing facility, who observed out that, "Good generic problem-solving skills are key [because] … early diagnosis that something is wrong, and what has gone wrong is important." Good technicians, then, have an aptitude for problem-solving when processes go wrong. Moreover, as another interviewee put it, good managers will harness this tacit knowledge by "tapping into the pool of plant-level information", noting that "the technicians go out onto the plant every day and they'll tell you what's wrong and how to fix it." As was noted above in the case of maintenance technicians, so too is it true of manufacturing technicians that their practical knowledge may even have input into the design of a process. As the head of R&D at one manufacturer put it, new processes "have to be rooted in operational reality" and manufacturing technicians' practical experience of putting processes into effect, and of dealing with problems that arise, sometimes enables them to them to provide advice about how a process should be designed so as to work well at scale. While valuable in all kinds of organisation, these problem-solving skills are arguably especially valuable in process development facilities, where the ability of technicians to identify the causes of problems, and to suggest solutions to them, is important in facilitating the optimization of the processes being developed. Such technicians make a very valuable contribution to the optimization of the processes in question. And, as noted above, in order to ensure that they possess the skills and knowledge required for them to be able to make this contribution, such technicians are typically qualified to Level 4/5.[22]

3.2.3.3 The skill level, and qualifications of manufacturing technicians

There appears to be some reasonably systematic variation in the precise level of skills and knowledge required of the manufacturing technicians employed by the manufacturers and process development organisations considered in this study, depending on the kind of organisation in which they are employed. In the case of those manufacturers that tend to produce just one product, using a well-established method of production, the process operators tend to be qualified to Level 3. This is the case in most (five) of the process development firms, and also in two of the manufacturers who specialise in contract manufacturing. However, even rank-and-file manufacturing technicians tend to be qualified to Level 4/5 (i.e. possessing an HNC, HND or Foundation Degree). The reason is that in such cases the manufacturing technicians will not simply be carrying out a single, routine production process. On the contrary, they will be required to put in practice a variety of novel, and sometimes experimental, processes, depending on the particular process that is being developed in the case of process development organisations, or on the particular kind of product currently being made in the case of the two contract manufacturers. Some aspects of those processes will almost certainly be unfamiliar to the technicians, who need a level of knowledge and skills above what is required to work in a standard manufacturing facility if they are to be able to respond flexibly and effectively to the demands of each new process. As the training manager of one such organisation put it, "80% of normal process operators couldn't do what our operators do." Or, in the words used by the operations manager of another process development plant, manufacturing technicians are

22 The Trailblazer standard stipulating the competences expected of a manufacturing technician working in the life and industrial sciences can be found in Appendix 3 of this report.

"not just valve-turners" who simply operate a plant in a routine way. Rather, they are "problem-solvers who can offer ideas around the process … who can see a flaw and say 'This is the solution'." The level of skills and knowledge required for technicians to be flexible, adaptable and knowledgeable enough to meet such challenges was said to in the region of Level 4/5.

It is also worth reflecting on the substantive content of the skills and knowledge required of the manufacturing technicians who work in industrial biotechnology. A tentative conclusion indicated by the data collected for this project is that the broad subject area in which manufacturing technicians need to be qualified varies somewhat according to which of the two kinds of production process distinguished above, namely those involving (i) large-scale industrial plants, and those centring on (ii) smaller-scale, laboratory or cleanroom-based fermentation, their employer is utilising. In the case of manufacturers that rely on large-scale industrial plants, manufacturing technicians tend to be qualified in subjects such as chemical process operations or manufacturing. As one interviewee put it, manufacturing technicians in organisations of this kind "need a physical [process engineering] toolbox, not a molecular toolbox."

In contrast, those organisations that manufacture in laboratory and/or cleanroom-type environments, and so make less use of heavy industrial plant, tend to employ as manufacturing technicians people who are qualified in subjects such as applied science or applied biotechnology, with more of an emphasis on laboratory rather than process operations skills.[23] And it is perhaps unsurprising, therefore, that it is organisations in the second of these two groups, but not in the first, that report that some of their manufacturing technician roles are filled by over-qualified graduates, who may possess the skills required to carry relatively small-scale fermentations and cell culture but who are highly unlikely to be able to operate large-scale industrial plant.[24]

Interviewees from firms that made use of something like a large-scale industrial plant were asked to reflect upon two issues.

- First, whether it would be easier to obtain manufacturing technicians for industrial biotechnology either (i) by converting process operators from the chemical industry, giving them the skills and knowledge of fermentation, cell biology, microbiology, etc., they would need to work carry out production in industrial biotechnology or (ii) by taking people who already have the relevant biological knowledge and equipping them with the relevant skills in process engineering.
- Second, depending on their answer to the first question, interviewees were asked to outline the additional skills and knowledge that would ideally need to be imparted to the chosen group of people in order for them to be equipped to work in manufacturing roles in industrial biotechnology.

So far as the first of these two questions is concerned, the consensus amongst interviewees was that it would be easier to take experienced chemical process operators and give additional training to equip them with the skills and knowledge needed to work as a manufacturing technician in industrial biotechnology than

23 See Medway School of Pharmacy (2016) for an outline of the content and structure of one such qualification, namely a Foundation Degree in Applied Bioscience Technology, introduced as part of the Higher Apprenticeship in Life Sciences and offered by the University of Kent (BIS 2011: 22).

24 Also see TBR (2016: 46).

to convert people who already had some knowledge of biology and give them the relevant process engineering skills. The reason interviewees gave for this conclusion is that, while the details of the manufacturing processes used in industrial biotechnology differ from those employed in standard chemical plants, there remains a good deal of common ground between the two. In particular, both are (usually) large-scale industrial processes, the broad contours, if not the details, of which will much more familiar to chemical process operators than to people who have only had experience of smaller-scale, laboratory work. As the operations manager of one manufacturing facility put it,

> *80% of understanding process operations is the same whether it's biotech or chemicals ... 20% looks at how biotech differs.*

Similar views were expressed by another interviewee, according to whom chemical process operators

> *would already have 90% of the knowledge they need – as a control valve is a control valve, a pump is a pump, a seal is a seal, a compressor is a compressor, etc., in chemical plant and in an IB plant.*

Consequently, according to the chief scientific officer of another manufacturer, experienced chemical process operators already have a 'good broad base' in the skills and knowledge required to work in industrial biotechnology:

> *Operators from chemical firms know what they're doing from a [broad/generic] operations perspective … they're good with health and safety, operational routines, quality controls.*

In contrast, while people who have had some scientific training but who have only worked in laboratories may know some of the biological principles relevant for industrial biotechnology, they will be unfamiliar with most of the features of large-scale, industrial process operations. Consequently, as one interviewee put it, "it's a 'big ask'" for such people to acquire the relevant expertise in process operations.

Essentially, then, interviewees argued that experienced chemical process operators would already be familiar with many of the broad features of the large-scale manufacturing processes required for industrial biotechnology plants, and so would require less training than people who were familiar with biological science but not with engineering and process operations. They are also more likely to be familiar with, and amenable to, the shift work required of manufacturing technicians in industrial biotechnology. Moreover, as we shall see in Section 3.3.2 below, when we discuss how firms have acquired their current manufacturing technician workforce, that this is not mere talk; the most common approach to acquiring manufacturing technicians involves employers hiring experienced chemical process operators and giving them additional 'top-up' training so that they possess the additional skills and knowledge required to work in industrial biotechnology.

Moving on to the second of the two questions mentioned above, in the case of those organisations that believe that it would be better to acquire manufacturing technicians by converting chemical process operators rather than laboratory scientists, the question arises of what additional skills and knowledge such converts need to be able to work effectively in manufacturing roles in industrial biotechnology.

The following were commonly mentioned amongst the list of practical skills that are specific to industrial biotechnology and that even experienced chemical process operators would have to acquire in order to be trained to work on an industrial biotechnology plant:

- Basic methods of cell culture, such as fermentation, involving both mammalian cells and bacteria (according to standard operating procedures).
- How to carry out manufacturing and sampling aseptically (that is, without introducing any contaminants into the processes).
- How to examine samples and (i) judge whether the cells are growing as they should and (ii) ascertain whether the process has become contaminated.[25]
- The use of cleanrooms, where required, including: how to use gowns and gloves; how to move about, and work in, a cleanroom; how to test the cleanliness of a cleanroom; how to clean a cleanroom.
- The ability to carry out production, including completion of the appropriate paperwork (e.g. batch records), in accordance with the requirements of the relevant regulations (including GMP, where appropriate).

Ideally, interviewees stated, these practical skills would be underpinned by the following theoretical knowledge:

- Basic cell biology, including knowledge about the following issues: what is a cell; how cells grow (e.g. a knowledge of anaerobic digestion); what controls cell growth; the difference between different types of cell, in particular between mammalian (eukaryotic) cells (e.g. CHO cells) and microbial or prokaryotic cells (such as bacteria or yeast).
- Basic microbiology, including information about topics such as the following: the nature of bacteria and micro-organisms; what is 'contamination', where does it come from, and why it matters; how the risk of contamination can be minimised.
- Principles of, and rationale for, Good Manufacturing Practice (GMP).

This underpinning knowledge is important because, as one interviewee put it, it "provides the basis for a number of practical tasks that are carried out." In particular, several interviewees argued, it is important for manufacturing technicians to possess this knowledge for two main reasons. First, it will help them to make informed judgments about how, within the margin of discretion afforded them by the standard operating procedures that govern their behaviour, they should act in response to various situations that might confront them in the course of carrying out their duties. For example:

- A knowledge of the fundamentals of cell biology will help technicians to understand how cells grow so that they understand why pH, oxygen levels, pressure, temperature, etc. need to be maintained within certain parameters in order for the production process to work properly. As one interviewee put it, technicians "have to understand what's going on inside the flask" in order to work effectively.

25 It is important for operators to be able to do this because they are often working on shift and therefore will sometimes lack immediate specialist back-up. It follows that they need to be able (aseptically) to sample and test cells themselves in order to be able to tell such things as whether the cells are dividing as they should, whether the cells' vitality and health is as it should be, and whether there is any contamination in the cell mass.

- A knowledge of cell biology is also important because it will drive home to technicians the fact that they are dealing with a living organism, whose development cannot simply be halted and may take significantly longer than most chemical reactions. It is important for technicians to appreciate this, several interviewees said, because it implies that bio-processes are typically less 'forgiving' and harder to recover from mistakes than chemical plants/processes, so people need to be aware that, 'If I do this incorrectly now, I'll be setting us back three weeks'. This knowledge will, it is hoped, encourage technicians to be vigilant in avoiding such mistakes in the first place.

Second, such underpinning knowledge was also said to be important because it will help the technicians to understand why compliance with the standard operating procedures is important, and why it is important for them to act consistently with those procedures, thereby encouraging compliance with them. Examples mentioned by interviewees include the following.

- In a similar vein, technicians need to have some knowledge of microbiology so they understand the basic principles of process contamination control, and are therefore aware of the importance of adhering to the relevant procedures.
- It is also helpful if technicians have a knowledge of the requirements for GMP manufacturing (where relevant), so that they understand the importance of adhering to the relevant procedures. As the Director of Manufacturing at one facility put it, "They can only comply if they have a framework [of knowledge] that enables them to comply … Also, they need to appreciate why [the regulations and processes] are not unnecessary and time-wasting [to encourage compliance]."

For all these reasons, therefore, as one skills development manager put it, "We don't need people who just push buttons … We need people who understand why [things are done a certain way]."

Having outlined the kinds of duties associated with key technician roles in industrial biotechnology, we move on to consider in the next section of the report how the employers visited for this study filled the technician roles they currently have in their organisations.

3.3 SOURCES OF THE CURRENT TECHNICIAN WORKFORCE

How were the technician roles that currently exist in the organisations visited for this project filled? Three alternative possibilities may be distinguished, although in practice of course any one organisation might adopt a mixture of these different approaches in its efforts to acquire the skilled technicians it needs.

The first approach is external recruitment, which involves the employer hiring people who are already trained well enough to fill the roles in question from the external labour market. In such cases, the workers in question are already sufficiently skilled at the kind of work they will be required to do, so that little if anything beyond induction training is required before they can work productively in their new role. It is worth noting that, in considering the possibility of filling technician roles by recruitment, two broad possibilities should be considered. The first is that such roles are filled by experienced recruits who possess intermediate-level qualifications (i.e. who are technicians). A second possibility, noted above, is that employers may fill such roles, not by hiring people with technician-level skills and qualifications, but by recruiting graduates. Where employers avail themselves of this second option, then – as noted above – we have a case of what is known as 'over-qualification'.

Second, and in sharp contrast, the employer might fill technician roles by training technicians in-house, via its own apprenticeship scheme. An apprenticeship is a contract between an employer and a (traditionally, young) person that combines a structured programme of on-the-job training and productive work with part-time, formal technical education (Steedman *et al*. 1998: 11; Lewis 2014a). Apprenticeship training, which is usually formally certificated, equips people with intermediate (Level 3-5) skills of the kind required to fill roles that fall under the heading of 'Skilled Trades' or 'Associate Professional and Technical Occupations' in the UK's Standard Occupational Classification system.[26] It follows from this definition that any training for roles whose occupants need only be semi-skilled (i.e. require no more than Level 2 skills) will not count as an apprenticeship, as it does not aim at the Level 3-5 skills that are the hallmark of apprenticeship training (cf. Steedman 2010: 3; Richard 2013 4-5, 33-35). Equally, training programmes that do not offer a substantial (20%) proportion of time spent on formal, off-the-job technical education and training, so that trainees can acquire the technical knowledge which underpins the practical skills, do not count as an apprenticeship.

A third possibility also involves the employer playing a role in training workers, but in a rather different fashion to what is involved in apprenticeship. This third approach will be referred to here as 'upgrade training'. It involves the employer taking people – who may be recent recruits or more established employees, and who may have a broad range of ages, prior levels of skill and qualifications – and giving them the specific training required to fill a particular technician role within their organisation. In contrast to apprenticeship training, upgrade training tends to be: closely tailored to the requirements of a specific role in a particular organisation; often provided informally, on-the-job, without any off-the-job technical education; and it is also often uncertificated. Upgrade training is typically more limited in breath, depth, generality, and duration than apprenticeship training, and tends therefore to be cheaper than an apprenticeship (Ryan 1995: 30-32; Ryan *et al*. 2007: 130, 137).

What balance did the organisations visited for this study strike between these different means of filling technician roles when they acquired their current technician workforce? Data on this issue proved hard to obtain, especially in those firms that had been established for some time, the reason being that in those cases in particular interviewees did not know how many long-standing technicians had been acquired. Nonetheless the following broad accounts of how the three kinds of technician role often found in organisations involved in industrial biotechnology seem to be supported by the evidence provided by interviewees. In each case, we shall consider (i) the strategies that organisations used in the past, in order acquire their current stock of skilled technicians, as well as (briefly) (ii) the (possibly different) approach that organisations are currently using as part of their efforts to acquire technicians and thereby build their future technician workforce.[27]

26 For the equivalent qualifications within the Scottish Credit and Qualifications framework, see www.scqf.org.uk/framework-diagram/Framework.htm

27 The latter issue will be explored in more detail in the next chapter of this report.

3.3.1 Laboratory technicians

As prefigured above, many organisations noted that the abundant supply of graduate scientists implies that advertisements for laboratory technician posts lead to numerous applications from people qualified to degree level or above. This supply of relatively cheap graduate labour has encouraged organisations to rely mainly upon the recruitment of over-qualified biological science graduates rather than vocationally-educated technicians to fill such roles. As one interviewee said of how those roles are filled in his organisation, "We'd like to hire a technician but all we get applying are graduates." The exceptions to this pattern were twofold. One manufacturer had trained a small number of laboratory technicians via an apprenticeship scheme in the past. Second, one manufacturer and one process development organisation had used upgrade training to obtain some of their laboratory technicians, taking people with no more than school-leaving qualifications and equipping them with the skills required to carry out laboratory technician duties via informal, on-the-job, in-house training (with no off-the-job technical education).

However, as also noted above, and as will be discussed in more detail in Section 4.2.2 of the next chapter, this reliance on over-qualified graduates is widely viewed as mixed blessing, due to the poor practical skills and limited loyalty displayed by many graduates. As a result, in looking towards the future, several organisations in the sample have recently begun to train their own laboratory technicians. By far the most common approach, adopted by ten firms, is apprenticeship training, with one firm adopting an upgrade training approach.

In the case of the acquisition of laboratory technicians, therefore, there appears to be something of a shift in approach under way, involving less reliance on the recruitment of over-qualified graduates to fill laboratory technician positions and with more use being made of apprenticeship training. We shall discuss the apprenticeship training programmes being used, and the reasons for this change, in more detail in the next chapter of this report.

3.3.2 Manufacturing technicians

Unsurprisingly, there was a consensus amongst interviewees that it is hard to recruit experienced manufacturing technicians who have a knowledge of fermentation and who can therefore slot straight into manufacturing roles without additional training. The reason is simple: since industrial biotechnology is a relatively new industry, there has not yet been time for the development of a pool of workers who have learned their trade in it. As the training manager from one manufacturer remarked, "There's little manufacturing in the UK aside from [company name removed] and a bit of [company name removed]" so there isn't a pool of skilled workers. Consequently, "it's hard to recruit ready-made people; there aren't many fermentation people out there." As the Chief Operating Officer of another firm put it, "Trying to get hands-on process technicians is hard … They're rare."

Against this background of limited availability of experienced IB manufacturing technicians on the external labour market, organisations adopted a variety of strategies in order to acquire the trained manufacturing technicians they currently employ.[28] The most common approach, which had been adopted by eight process operators and manufacturers in their efforts to acquire their current technician

28 Moreover, as prefigured above, organisations did not confine themselves to just one of these methods, but rather tended to use a combination of approaches in order to fill technician roles.

workforce, centred on a variation of the recruitment approach, involving what might be described as 'recruitment and supplementary or top-up' training. More specifically, the organisations in question recruited people who had already received significant levels of education and training outside industrial biotechnology and then, having hired them, gave them additional ('top-up') training so that they have the specific skills and knowledge required for industrial biotechnology. For example, the manufacturers whose operations centred on large-scale industrial plant acquired most of their technicians by hiring experienced chemical process operators, and then augmenting their existing process operations skills by giving them additional training in the specific techniques and underpinning knowledge for IB. In the words of the operations manager of one manufacturer that adopted this approach, "There isn't the depth of people due to IB being a new industry so we look to take experienced chemical process operators and give them specialist training." A similar strategy was often adopted by the organisations whose manufacturing operations centred more on laboratories and cleanrooms, the one difference being that sometimes the recruits in questions included science graduates (who were therefore, as noted above, over-qualified, though not necessarily over-skilled, for the role of a manufacturing technician). If we change focus from the current to the future technician workforce, then we might also note that one more expanding manufacturer intends to adopt this approach as one of the ways it will acquire manufacturing technicians in the future.[29]

The second most common approach, which was utilised by four organisations as one of the methods they used in the past to acquire their current stock of trained technicians, and also to meet at least part of their future need for technicians, centred on upgrade training. This approach involved the employer in question taking people who had little prior experience of any kind of manufacturing or process operations, and then training them from scratch in the specific skills required to fill the role of a manufacturing technician within their organisation. Typically, the training in question is provided on-the-job by more experienced staff members and does not involve formal, certificated off-the-job technical education. Turning from the origins of the current technician workforce to the source of future technicians, we note also that one expanding manufacturer is currently using this upgrade approach to train a manufacturing technician, while two process development organisations that are growing and therefore about to create some new manufacturing technician roles intend to fill these positions via upgrade training, taking young people who have just taken A-levels and training them on-the-job to become fermentation technicians.

Finally, three organisations – two manufacturers and one process developer – have acquired some of their current manufacturing technicians via apprenticeship training. Moreover, apprenticeship training looks set to increase in significance as a source of manufacturing technicians in the future. Three more organisations currently have apprentice manufacturing technicians, while another is seriously planning to do so.

29 For details both of these training programmes, and also of the other alluded to in what follows, see Sections 4.2 and 4.3 below.

3.3.3 Engineering technicians

The organisations visited for this sample have tended to rely either on recruitment or on apprenticeship training in order to acquire maintenance technicians. Recruitment was thought to be relatively straightforward in the case of mechanical and electrical maintenance technicians. However, matters were rather different in the case of control and instrumentation technicians, who were commonly held to be hard to obtain via the external labour market.[30]

It is noteworthy, therefore, that of the five organisations visited for this study that train apprentice engineers, four train apprentice control and instrumentation engineers. Moreover, one of those organisations has also chosen to respond to the difficulty of hiring experienced control and instrumentation technicians by developing an upgrade training programme designed to train some of their existing process operators as control and instrumentation technicians. One advantage of this approach is that those process operators already know both the process and in particular the DCS system through which the plant is controlled very well, so that when they come to work on the control and instrumentation systems on the plant, they are able to do more to tailor their work to the needs of the process than they would if they were not so well acquainted with it.[31]

30 For similar findings, see TBR (2016: 49). Difficulties in recruiting experienced control and instrumentation technicians have also been reported by firms in the chemical industry (Lewis 2013a: 24-25, 38).

31 Interviewees from Skills Development Scotland reported that the Scottish government has developed a similar scheme designed to help companies obtain control and instrumentation technicians by offering upgrade training to their process operators.

SECTION 4
THE FUTURE TECHNICIAN WORKFORCE

Having considered the technicians currently working in industrial biotechnology, whose acquisition reflected recruitment and/or training strategies adopted in the past, we proceed now to consider how employers in that sector are planning to satisfy their future need for technicians, focusing in particular on the balance they expect to strike between recruitment and training and, within the latter category, between apprenticeship and upgrade training.

4.1 RECRUITMENT

We explore first how easily employers in industrial biotechnology can hire experienced, work-ready technicians of the kind they need.

As noted in the previous chapter of this report, only three of the 21 organisations that currently employ laboratory and quality control technicians had used in-house training to fill those roles in the past. The vast majority of organisations reported that they acquired their current laboratory technicians via external recruitment, more often than not by hiring over-qualified graduates. However, the often disappointing practical skills, and limited loyalty, of these workers has begun to lead to an increasing interest in apprenticeship training, with no fewer than seven of the organisations visited for this study recently beginning to train their own laboratory technicians (with an eighth planning to do so). By far the most common approach, adopted by seven firms, is apprenticeship training, with one firm adopting an upgrade training approach.

We move on to consider next how employers are planning to acquire the manufacturing technicians they need in the future. As noted above, the organisations visited for this study have typically found it difficult to recruit experienced industrial biotechnology manufacturing operators ready-made from the external labour market in the past, for the simple reason that industrial biotechnology is too young an industry for there to have developed a pool of workers who have learned their trade in the industry. The consequent scarcity of such workers has forced firms to rely instead on a variety of different forms of training. The approaches adopted in the past have ranged, in descending order of popularity, from what were described in the previous chapter as 'recruitment and top-up' training, through upgrade training, to apprenticeships.

Interviewees reported that, notwithstanding the fact that more manufacturing technicians are being trained through the programmes just described, they expect to continue to find it difficult to recruit experienced, IB-ready manufacturing technicians. The reason is that the industrial biotechnology industry is expanding, both because new firms are being set up and also because – as noted above – more and more firms are increasing the scale of their operations up to the point where they find it worthwhile to create dedicated manufacturing technician posts. As one employer put it, "We see locally quite a lot of organisations expanding", which will of course increase competition for those workers who are available. And in the face of this continued scarcity of experienced IB manufacturing technicians, employers realise that they will have to continue to engage in some form of training.

Two features of this continued reliance on training are worth emphasising, before we consider in more detail some of the relevant programmes. The first is that, in seeking to recruit people whom they will subsequently train either via top-up or upgrade training, several employers that relied principally upon laboratory and cleanroom methods of production emphasised in particular the paramount importance of the recruit's attitude, over and above any prior experience (s)he may have had of working in a process-based industry.[32] In a phrase that was echoed by several interviewees, a senior operations manager from one manufacturer summarised his firm's approach to acquiring manufacturing technicians, which centres on the upgrade training of people with a wide variety of prior qualifications, by using the phrase, "We hire for attitude, and train for skill … We're not so interested in people's qualifications [when they are hired] but more in their attitude to the work, in particular the compliance element." The rationale for this approach is that it is easier to augment people's skills through training than it is to shape their attitudes. As the HR manager from another manufacturer put it, "We can train the skills … It's more about hiring for behaviours … It's your personality [that's important]." The attributes that were sought in potential recruits were reliability, discipline and, in particular, a willingness and ability to adhere rigidly to standard operating procedures and quality assurance guidelines (especially, where relevant, those associated with cGMP).[33] As the manager of an expanding process development organisation put it, we will be "taking people on board because of their 'innate skills' such as attention to detail, not cutting corners, and the ability to follow a standard operating procedure accurately."

The second noteworthy feature of the continued reliance on training to obtain manufacturing technicians is that, as noted above, there has been an increase in the number of organisations training apprentice manufacturing technicians. Six organisations – three manufacturers and three process developers – currently train apprenticeship manufacturing technicians, with three of them having just started doing so. Moreover, another manufacturer is seriously considering following suit.

Finally, it is worth noting briefly that of the ten organisations that stated that they employed engineering maintenance technicians, half train apprentices. This trend looks set to continue, especially in the case of control and instrumentation engineers, whose scarcity was noted in the previous section.

We move on now to consider in more detail the apprenticeship and upgrade training programmes in which employers in IB are engaged.

4.2 APPRENTICESHIP

4.2.1 Definition and involvement

As noted in Section 3.3 above, an apprenticeship is a programme of learning combining on-the-job training and experience at a workplace with part-time, formal technical education. Apprenticeships normally take at least two years to complete, after compulsory general education, are usually – though not invariably – formally certificated, and equip people with intermediate (Level 3-5) skills of the kind required to fill roles described as 'Skilled Trades' and 'Associate Professionals and Technical Occupations' within standard occupational classification systems.

32 Prior experience is more important in the case of those process technicians who are working on a large-scale industrial plant.

33 The limited scope for discretion in such roles is indicative of the fact that they are technician, not graduate, roles. Highly-skilled graduate work is typically associated with considerable employee autonomy and discretion, whereas tighter managerial control and a greater reliance on routinisation is associated with sub-graduate level work (Gallie *et al*, 2004).

Table 2: Involvement of the case study organisations in apprenticeship training, by type of organisation and role

Type of organisation	Number of cases	Number of employers currently offering apprenticeship training for various technician roles		
		Laboratory technicians	Manufacturing technicians	Maintenance technicians
R&D	12	3	0	0
Process development	9	2	3	1
Manufacturing	9	5	3	4

4.2.2 Apprenticeship training for laboratory and quality control technician roles

Ten organisations currently train or, in one case, are planning to train, apprentice laboratory and quality control technicians.

In seven cases, the apprentice is taking an apprenticeship at Level 3, in a subject such as Laboratory and Related Technical Activities or Applied Science. In these cases, a typical set of entry requirements would be five GCSEs at grades A*-C, including maths, English and a science. In three cases, two of which are R&D organisations, the employer in question has taken on a Higher Apprentice in Life Sciences, the precise subjects being either Applied Bioscience Technology (at Foundation Degree level) or Applied Biology (at HNC level). In the former case, the entrance requirement was three A-levels, including biology and at least one other science subject at grade C or above, while in the latter case candidates were required to have three Bs in relevant A-levels.

As suggested in Section 3.3.1 above, the rationale for taking on these apprentices is typically twofold: an appreciation that, especially as an organisation grows, there is often quite a lot of mundane work, for which a degree-level qualification is not required; and a realisation that, while there may be a plentiful supply of graduates, they often lack practical skills, and also often become disenchanted with the routine nature of the work and relatively low pay associated with technician roles, leading to high turnover.

Both of these factors were mentioned by interviewees from the organisations that had recently take on apprentice laboratory technicians. One R&D company that has just taken on its first laboratory technician apprentice said that it had looked at the tasks its PhD-qualified scientists were carrying out and saw that they involved "too much low-level work." The organisation's response was to create a more advanced division of labour, whereby the "PhDs will get the process sorted out [i.e. specified] while the technicians will keep the established process running." This change was also driven by a "commercial imperative" as it is cheaper to have the work done by the technician. In a similar vein, the manager of an expanding process development firm, who views its decision to start taking on apprentices as "a cost-effective way of adding to our capabilities" as the organisation grows and a more elaborate division of labour becomes possible. His views were echoed by the HR manager of a manufacturer that has recently begun to take apprentices, who explained that, "the goal of growing talent [via apprenticeships] is to develop specialist technicians who can free PhDs to concentrate on higher value work …

From a cost perspective, it's more cost-effective to have technicians do routine work." In this way, the interviewee continued, the apprentices "add value to the business." This was especially the case, according to the head of R&D in one company which has just taken on a Higher Apprentice, because people who have come up via the apprenticeship route have better practical skills than many graduates.

This case study evidence may be brought to bear on the question of the balance that Science, Engineering and Technology employers strike between employing university-educated graduates and vocationally-educated workers to fill roles in their organisations (Mason 2012: 25-27). Mason notes that over the past 10-15 years employers have been motivated to employ graduates straight out of university to fill such roles, primarily because they do not incur the cost of training them, whereas they do pay for at least part of the cost of training those workers who have been developed via a work-based route. However, Mason also cites recent case study evidence showing that employers' frustration with the limited practical skills and experience possessed by graduates is now prompting some employers to rethink their strategy for acquiring skilled workers, leading in particular to a greater reliance on work-based training. The evidence concerning laboratory and quality control technicians presented above provides further support for Mason's conjecture that there is something of a shift underway, with employers turning towards apprenticeships to fill technician roles because people coming up via the work-based route are more likely than those who followed a more narrowly academic path to have the practical skills needed by businesses.[34]

4.2.3 Apprenticeship training for manufacturing technician roles

Six organisations currently train apprenticeship manufacturing technicians. Their choice of apprenticeship programme typically differs according to whether the production process they use involves large-scale industrial plant or smaller-scale laboratory and cleanroom work.

In the case of all three of the organisations whose manufacturing activities involve large-scale industrial plant, the trainee manufacturing technicians are taking Level 3 Apprenticeships in subjects such as Process Operations, Process Technology, or Manufacturing. The apprentices in question were typically required to have passed five GCSEs at grade C or above, including maths, English and science. The organisation that is planning to take manufacturing apprentices, which also engages in manufacturing using large-scale industrial plant, also intends to take process apprentices.

Matters are a little different in the case of the three organisations whose manufacturing involves smaller-scale facilities. In keeping with the account given in Section 3.2.3.3 above of the skills and knowledge typically possessed by manufacturing technicians in such organisations, the apprentices are studying for qualifications that place more emphasis on scientific knowledge, and less on engineering/process operations, than their counterparts who are being trained to work in industrial plants. More specifically, two of the employers are developing their manufacturing technicians through a Higher Apprenticeship in Life Sciences, while the third is doing so by having the apprentices take an HNC in Applied Biological Science. These three organisations are either contract manufacturers

34 For similar points in the case of the aerospace and chemical industries, see Lewis (2012b: 29-33) and Lewis (2013a: 17-18, 21-22) respectively.

or process developers, the nature of whose activities requires manufacturing technicians to possess a higher level of skills than is necessary for more routine manufacturing. Hence the fact that the apprentices in this second group of organisations are working towards Level 4/5 qualifications, rather than the Level 3 qualifications at which apprentices in the first group are aiming. In these three cases, potential apprentices were required to have A-levels or the equivalent, including at least one science subject, at grade C or above.

The rationale that a majority of these organisations gave for taking apprentices is straightforward: namely that they do so in order to ensure that they can obtain the skilled manufacturing technicians they need as they expand their activities, in the face of the limited number of experienced technicians available for hire on the external market. As the training manager of manufacturer succinctly put it, "We can't get technicians off the shelf, so we take apprentices." Technicians who had been trained in-house, via apprenticeships, were also said to be better than many graduates at applying their skills to the kinds of practical problems that arise in the workplace. In the words of one operations manager, "If you compare apprentices and people who've been to university for the same length of time, the apprentices are more highly-skilled than the graduates … They're experts in the techniques."

One other advantage of training apprentices, mentioned by a smaller number of organisations, is that it gives employers an opportunity to take young people and, at a formative age, to socialise them into the organisation's culture, so that they acquire the habits and modes of thought – concerning in particular the tolerances and standards to which work has to be done, and the importance of adhering rigidly to the standard operating procedures and quality assurance regime – prevailing in the organisation for which they work. In the words of one interviewee, "Apprentices have got no baggage and you can mould them as they tend to be quite open." Of course, it is possible to do this with older workers, whose habits have already been formed but may be susceptible to modification. Indeed, this is one of the goals of the top-up training that has hitherto been the primary method of acquiring manufacturing technicians for so many firms. However, as one operations manager put it, if you take people who have worked in other industries, then you "need to re-programme folk to work in a different environment" of the kind found in industrial biotechnology, especially where manufacturing takes place under a cGMP regime. But it is easier to inculcate the appropriate attitudes with younger people, who have not yet become wedded to practices used in their old firms that might not be so relevant in industrial biotechnology.[35]

4.2.4 Apprenticeship training for maintenance technician roles

Five of the organisations visited for this study – three manufacturers and two process development firms – train apprentice maintenance engineers. In three cases, the schemes are well-established. The other two, however, have been set up relatively recently, as indeed have the two organisations that run them.

Engineering maintenance apprentices are initially enrolled on a Level 3 Apprenticeship in Engineering. However, in four of the five cases, subject to satisfactory performance they will have the opportunity to progress on to an HNC in engineering. Apprentices typically need to have five GCSEs at grades A*-C, including English, maths and science, although some organisations required a 'B'

35 Similar points have been made in the case of another industry with very exacting quality assurance procedures, namely the UK space sector (Lewis 2012a: 27).

grade in mathematics on the grounds that this will help the apprentices cope with the off-the-job college courses required as part of their training.

Two of the organisations that are training apprentice engineers are expanding, and see the apprenticeship programme as a means of acquiring the skilled labour they need. One viewed the apprenticeships as a means of succession planning, given the age of its maintenance technician workforce. As noted above, a difficulty of recruiting experienced control and instrumentation technicians was cited by a number of organisations as a reason for training apprentices in that branch of engineering.

4.2.5 Impediments to the use of training to develop technicians for industrial biotechnology

Some organisations that currently take apprentice manufacturing technicians, or are thinking seriously about doing so, have found it difficult to find a local college or university willing to offer the off-the-job course through which apprentices acquire the technical knowledge that underpins their practical skills. As one training manager put it, "There is no college capable of giving us what we currently want." The reason lies in what might be called 'the tyranny of small numbers', namely the problem that the total number of students wanting to take the courses in question is insufficient to make it worthwhile, given the prevailing funding regime, for colleges to offer them. As the training manager from one of the employers summarised the problem, the difficulty stems from the fact that "IB is an 'embryo business'," which means that there is not the critical mass of apprentices in one geographical area required to make it worthwhile for colleges to offer specialised courses. The upshot is that, "We get lost in a sea of other interests." This problem is not an unique to employers in industrial biotechnology. Employers using other emerging technologies, and from other emerging industries, have also struggled to persuade colleges to offer the training their apprentices need. Employers in the UK space industry, for example, have found it hard to persuade colleges to offer the HNCs in electronics they would like their technicians to take, while firms in the composites industry have also found in hard to find colleges willing and able to offer high-quality training in that field (Lewis 2012a: 31, 2013b: 5, 46-47).[36]

The reason for these problems is straightforward. As Wolf (2015b: 5-6, 9-12) has argued, the current system of apprenticeship funding encourages providers to focus provision on shorter, cheaper, lower-level programmes, rather than the longer, more expensive, higher-level apprenticeships required by employers in areas of advanced manufacturing such as industrial biotechnology. This is so, Wolf argues, for two main reasons: first, such courses are easier to pass, so that it is easier for providers to claim funding for them under the current 'output-related' funding system; and also, second, because for any given level of difficulty, if a provider offers a large number of shorter courses, then the risk of it suffering an unexpected shortfall of income because of an unusually high number of failures in any one group is reduced if that risk is spread over a larger number of cohorts (rather than a smaller number of groups on longer programmes). The upshot is a situation where training providers all-too-often lack the incentive to offer the kinds of courses needed by employers in advanced manufacturing who wish to train apprentices.[37]

36 As the UKCES has noted, 'Part of the problem [with the UK's relatively low number of apprenticeships] is that there aren't enough high quality technical institutions with genuine employer leadership, to deliver advanced technical education. There has been lots of innovation, including the new National Colleges in England, but these will take time to embed and a greater scale of change is needed' (UKCES 2014: 19).

37 Wolf (KCL 2015a: 32) highlights how most of the recent increase in apprentice numbers has been concentrated in low-cost areas, and also at below Level 2. For more general concerns about whether the incentives that encourage the FE sector to provide training in STEM disciplines are sharp enough, see Skills Commission (2011: 10-11, 23-27) and Wolf (2011: 60).

One case study organisation has responded to this problem by utilising a local college course that is more general, and so not as well tailored to the needs of industrial biotechnology, as it would like. Two others have dealt with the problem by having their (higher) apprentices acquire the relevant underpinning knowledge, not by going on day release to a local college, but rather by having them take a Foundation Degree in Applied Bioscience Technology via distance learning programme offered by a university from outside their local area. The trainees in question will rely on online learning through most of the academic year, supplemented by block release summer schools.[38] A fourth employer is considering how it might augment its own supply of apprentices with trainees from other industrial biotechnology companies in the same area.[39] We will return to this issue below, in Section 5.

4.3 TOP-UP TRAINING

It was noted above that the most popular way in which organisations obtain manufacturing technicians involves what was described above as 'recruitment and supplementary or top-up' training. This involves the organisations in question hiring people who have already received significant levels of education and training, and then giving them additional training in order to equip them with the particular skills and knowledge required to work as a manufacturing technician in industrial biotechnology.

Some of the training programmes in question are highly structured, especially in larger organisations. An example is provided by the way in which one firm trained the manufacturing technicians who would operate its pilot plant. The experienced chemical process operators who were the typical recruits for the training programme were first of all given an intensive week-long off-the-job course designed to introduce them to IB, by giving them a basic knowledge of cell biology/ fermentation and microbiology/aseptic techniques. This was followed by a 6-month programme of structured on-the-job training.

An analogous approach was adopted by another manufacturer whose production processes centred more on the use of cleanrooms and smaller-scale fermentation rather than large-scale industrial plant. This organisation offers recruits, drawn for example from the food industry, a structured programme of on-the-job training designed to build on their existing skills and to enable them to become manufacturing technicians in its cleanrooms. Typically, recruits start with simple tasks that involve them supporting the activities of the experienced manufacturing technicians, for example by learning how to prepare the materials and equipment used in manufacturing. Later, as their skills develop, they progress to learning how to carry out laboratory-based fermentations according to standard operating procedures. Training of this kind was typically provided on-the-job, by the employer, and was uncertificated (that is, it did not lead to a formal qualification).

38 One of the R&D companies that is training a laboratory technician via a Life Sciences Higher Apprenticeship, as mentioned in the previous section, has adopted the same distance learning approach.

39 Another organisation that wished to use an apprenticeship to train some of its manufacturing technicians responded to this problem by providing the trainee with on-the-job training only, effectively abandoning the apprenticeship – for which off-the-job training is essential – and using upgrade training instead.

4.4 UPGRADE TRAINING

Recall from Section 3.3 that upgrade training is normally provided only on-the-job, with little if any off-the-job vocational education. It tends to be closely tailored to the specific requirements of the particular job role for which the person is being trained by the employer in question, is often uncertificated, and may be given to trainees with a wide variety of ages and (initial) levels of skills and qualifications (including young people who have only recently finished their A-levels). Upgrade training was used by some of the organisations considered in this study, to train both laboratory and manufacturing technicians.

Two manufacturers that use upgrade training to acquire some of their manufacturing technicians take school-leavers with A-levels and offer them a structured programme of in-house training designed to equip them with the skills required to carry out fermentations. The training is delivered entirely on-site by the manufacturers' own staff and involves no off-the-job vocational education. Given the centrality of the blending of technical (occupational) knowledge and practical (occupational) skills for apprenticeship, this implies that the programmes in question do not count as apprenticeships. Once again, the first part of the training involves recruits learning how to prepare the materials and equipment required for manufacturing. Once those tasks have been mastered, trainees move on to learn how to operate the bioreactors used in manufacturing, according to standard operating procedures specified by senior colleagues. Both of the organisations set great store by the attitude of the people recruited on to these upgrade training programmes, arguing that they will "recruit [trainees] on the basis of attitude, not knowledge." In a similar vein, one manufacturer has trained some of it laboratory technicians via upgrade training, involving on-the-job training from a more experienced member of staff in such tasks as media preparation, aseptic sampling, etc., but with no off-the-job training or certification of their skills.

Another manufacturer offers a highly-structured 2-year programme of upgrade training for people without prior experience of process industries, intended to equip them with the skills required to work safely and effectively on its industrial plant. The programme involves an initial period of instruction from the workplace at an industrial training facility, so trainees could learn the basics of working on a large-scale industrial plant. This was followed by on-the-job training on the various parts of the production process, divided into twenty modules that taken together add up to a comprehensive all-round knowledge of the plant and production process. Trainees are tested after each module to check that they have mastered its contents. The training is not, however, formally certificated, though the organisation is considering the possibility of mapping their programme onto the requirements for an NVQ, in which case trainees' skills would be certificated. There is no off-the-job technical education.

SECTION 5
TRAINING: ISSUES AND POTENTIAL SOLUTIONS

This section considers various issues concerning education and training programmes for technicians working in industrial biotechnology.

It was noted above that some employers that have tried to set up apprenticeship training programmes have found it hard to obtain training. It should also be noted that some of the training providers visited as part of this study have offered training courses in industrial biotechnology, but have found it hard to attract sufficient trainees for it to be worthwhile for them actually to offer the courses in question. One provider that has tried to offer courses has had to cancel some of them due to low take-up. As another provider that is considering offer training has put it, "The training demand is not there yet."

Both of the difficulties just described stem from what was described above as 'the tyranny of small numbers'. This is the problem that, while there is some demand for the training programmes, all too often the total number of trainees wanting to take the courses in question is too small to make it worthwhile for providers to offer them, given the prevailing funding regime. The upshot is an outcome where you have both frustrated employers, who cannot access the training they want, and also frustrated training providers, at least some of whom are in principle willing to offer courses but find it imprudent to do so in practice.

It is worth unpacking the problems faced by training providers in a little more detail, because doing so will point towards some of the issues that need to be taken into account in thinking about potential solutions.

- The first, and most obvious, source of the problem is the lack of current demand for training courses. Of course, this mainly reflects the relatively small size of the industry, which implies that the number of trainees is likely to be correspondingly small.
- The second aspect of the problem concerns future demand. If a provider is going to find it worthwhile to make the investment in staff and equipment required to provide high-quality training, there must be the prospect of more than one decent-size cohort of trainees. Training providers will need there to be sustained or repeat demand, so that there is a demand for their courses which is sustained over enough cohorts or years of trainees for them to earn a decent return on their investment.

Uncertainty over both the immediate demand for training courses, and also concerning whether the demand for training is likely to be sustained for long enough to make it worthwhile to invest in the relevant tutors and facilities, can makes providers reluctant to offer training.

What can be done to overcome these problems? In keeping with the points just made, ways need to be found both to aggregate the demand for training, so that the number of trainees reaches or exceeds the threshold required to make it worthwhile for providers to offer training, and also to reduce the risk faced by potential training providers. One obvious way of aggregating demand, and also of reducing risk faced by providers, is to share or combine as much as possible technician training for industrial biotechnology with training for other process and science-based industries. For example, as noted above, there is a good deal of overlap between the skills and knowledge needed by manufacturing technicians in parts of industrial biotechnology and in the chemical industry. What that means, of course, is that a good deal of training for manufacturing technicians in industrial biotechnology should be able to piggy-back on existing provision for chemical process operators, albeit with the addition of some modules dedicated to industrial biotechnology. It is interesting to note in this context that interviewees were almost unanimous in stating that there is no need for a bespoke IB apprenticeship; it would suffice to take a chemical process engineering programme and tweak it to include modules on basic cell biology, fermentation, and microbiology. Such a strategy would be in keeping with the Trailblazer approach to apprenticeships, as driven by Cogent and the Science Industry Partnership (SIP) in the case of the process industries.[40] The Trailblazer approach highlights the importance of apprentices receiving training that is broad enough to enable them to work in an occupation, such as that of a manufacturing technician, in a variety of different firms and sectors (rather than the training being closely tailored to the needs of specific firms in specific sectors). That of course implies that a considerable part of the training should be generic or cross-sectoral, which is exactly what is being suggested here.

Even where this is possible, there remains, of course, the need to ensure that there is sufficient demand to entice providers into offering the IB-specific parts of the training programme. Again, the challenge is to aggregate demand so a 'critical mass' of trainees is reached. A number of points are relevant here.

The first point to note is that, given the overall limitations of the demand for training, there is likely to be a need for only small number of such providers. Ideally, these centres of excellence would be located in areas where there is a significant concentration of IB employers (cf. UKCES 2014: 19 and Department for Business, Innovation & Skills and Department for Education 2015: 18). A notable example of what is possible may be found in Scotland, where an HND in Industrial Biotechnology has recently (2015) been established at Forth Valley College and Glasgow Kelvin College (see Forth Valley College 2016 for an outline of the course). Three features of this endeavour are worth noting. First, the industrial biotechnology industry in Scotland is sufficiently concentrated geographically that many employers can send trainees on this course, helping to increase demand. Second, Forth Valley College in particular already offers intermediate-level courses in both Chemical Process Engineering and Applied Biology, facilitating the creation of a programme that combines elements of the two. Third, as suggested above, the programme is broad, offering modules in laboratory skills and in process operations/chemical engineering, as well as in chemistry and cell biology. This should make it a suitable vehicle, or technical certificate, for the off-the-job technical education and training of young people aiming for a variety of technician roles, including both manufacturing technicians and laboratory technicians, as well as making it possible for students to progress on to the third year of relevant

40 The SIP is a partnership of employers, drawn from science-based industries and supported by Cogent, whose goal is to help developed a skills system that will ensure that employers in those industries have the workers they need to develop a successful, globally-competitive set of science-based industries in the UK (SIP 2014, 2015). To that end, in addition to developing standards of competence for technicians, the SIP has sought to develop and promote a variety of training programmes, including apprenticeships. It was initially funded for three years, starting in 2014, via the government's Employer Ownership of Skills Programme. However, that funding was subsequently curtailed, ceasing in 2016. The SIP is seeking to continue as a membership organisation, with GTA services being one of the benefits enjoyed by members.

undergraduate degrees. A second example of such a development is considered below, when the activities of the National Horizons Centre are discussed.[41]

Second, in order to extend their reach beyond the area in which they are located, providers of IB-related training – especially the centres of excellence just described – should consider offering training via distance learning, supplemented by periodic residential courses or stints of block release, as a way of aggregating demand across a wider geographical region than would be possible using the more common model of day release to a local college. It is also important to publicise widely the existence of such distance learning options, so that employers are aware of their availability, a task for which the Science Industry Partnership (SIP) seems well suited.

Third, it should also be possible to offer some or all of the IB-related modules as CPD for more established workers, especially in firms that are considering adopting some element of industrial biotechnology in their production processes for the first time. This should increase the demand for the training, thereby reducing further the risk borne by training providers.

Fourth, one way of reducing the risk faced by potential training providers is to utilise existing facilities, which are also used for purposes other than training (perhaps most notably, process development organisations such as Catapult centres and the like). The use of existing facilities to provide training will help to reduce both the size, and the riskiness, of the investment required to set up a training programme: it will reduce the size, because some of the relevant equipment and personnel will already be in place; and it will reduce the risk because the facilities can be used to generate income from sources other than training, such as research/process development work; whereas a specialist training facility would be redundant if no trainees came to it, providers could instead use facilities and people that are also used for other activities. So, for example, one process development organisation visited for this study reported that its facilities are not always being fully used by client firms trying to test out their ideas, and suggested that as a result they could be used for training: "Training," the facility manager said, "is an obvious strand of work to bring in funding." Another prime example of this approach is provided by the National Horizons Centre. This is a partnership between Teesside University, the Centre for Process Industries (which is part of the High Value Manufacturing Catapult), and Darlington College. The Centre will provide training at several levels, from Level 2 up to MSc and PhD. What is of particular interest for this report is that, working in conjunction with local FE colleges and universities, the Centre will provide training in intermediate level skills, both for Level 3 apprentices and also for Level 4/5 Higher Apprentices, in accordance with the recently established Trailblazer standards for Laboratory, Maintenance and Manufacturing technicians, and that this training will involve "an emphasis on hands-on experience of typical bio-processing equipment" (see CPI and Teesside University 2015: 8).

Another advantage of using process development facilities, in particular Catapult centres, as the locus for training is that such an approach promises to provide a way of ensuring that training programmes and syllabuses are kept up to date and so remain attuned to the needs of industry. A notable feature of emergent industries such as industrial biotechnology is that the technologies and processes

41 Another example of a partnership between employers in industrial biotechnology is the 'Biotrain' programme, a partnership between employers and community colleges in the US state of Maryland, that has led to the creation of training programmes in soft and technical skills for entry-level roles in biotechnology (see www.biotrain.org/about-us.html).

used by employers are in many cases still being developed. If skills and knowledge of technicians are to keep pace, then training programmes need to be updated in line with emerging approaches to manufacturing. Given that their principal role as process development and scale-up organisations gives them early access to developments in technology, Catapult centres such as the Centre for Process Industries (CPI) ought to be well-placed to distil off the implications of those new developments for technician skills and knowledge, and to use them to inform the development of appropriate training programmes. As one interviewee said of these organisations, "Their research and process-development functions give them a constant flow of information" about new skills needed by firms using emerging technologies, which they can feed into training programmes at all levels.

If the CPI and similar organisations did this then they would be moving more closely into line with similar organisations elsewhere in the world, such as Germany's Fraunhofers and Singapore's 'Singtechs'. The targets for, and performance indicators used to evaluate, these non-UK institutions encourage them to devote systematic attention to skills development as one of the key contributors for the successful scale-up and commercialisation of emerging technologies. As one interviewee said of Singtech, "Training is hardwired into its KPIs." Consequently, they have a clear incentive to take a systematic and sustained role in skills development. In contrast, the remit of the UK Catapult centres is more narrowly conceived; the key performance measures used to evaluate UK Catapult centres focus on the value of commercial business obtained and grants won, not on measures of skills development, so that there is less of an incentive for these organisations to focus on skills development in a systematic and sustained way (Lewis 2014b). The explicit inclusion of (indicators of) skills development as one of the benchmarks against which Catapult centres are assessed would help both to ensure meaningful acknowledgement of the work they are already doing, and also to encourage them to continue with and develop their role within the skills system.

Another important consideration is provided by a recent shift in government policy, which promises to change the funding regime under which apprenticeship training is provided. In its 2015 Autumn statement, the government announced that it will impose a so-called apprenticeship levy (Department for Business, Innovation & Skills and Department for Education 2015; HM Government 2015a; also see Wolf 2015b). This will involve the government imposing a payroll tax of 0.5% on employers with a turnover in excess of £3 million, with the funding being used to create a National Apprenticeship Fund, the resources of which will be used to subsidise those employers who train apprentices. The goal of the levy is to shift the incentives facing training providers away from the lower-level apprenticeships, in areas such as customer services and business administration, towards intermediate-level qualifications in STEM subjects such as those suitable for employers in industrial biotechnology. In this way, it is hoped, it will become easier for employers to obtain access to the apprenticeship training they want. As Wolf (2015b: 16; also see pp 21-22, 25 n. 28) notes, "The purpose [of the levy] is to shift incentives, substantially, at the margin [towards high-quality apprenticeships]." Significantly, if the implementation of this scheme does indeed lead to an shift in incentives, and thereby to an increase in the number of genuine (Level 3+) apprentices being trained in STEM disciplines, then it should also help to alleviate the problem of the 'tyranny of small numbers', simply because there will now be more apprentices needing training, both now and in the future, thereby making it more worthwhile for providers such as FE colleges to incur the fixed costs of making the relevant investment in tutors, workshops, and so on.

The levy is part of a set of policy reforms intended by the government to increase the influence that employers have over the content of vocational training provision (Department for Business, Innovation & Skills and Department for Education 2015; HM Government 2015a; also see Richard 2012, Wolf 2015b). Such 'employer leadership' is thought to be important for ensuring that the UK vocational education and training system serves employer needs. However, employer leadership is costly and some employers may lack the experience and expertise required to access the skills system effectively and at reasonable cost in terms of time and other resources. This is especially likely to be a problem for small and medium-sized enterprises (SMEs), who may not have a dedicated human resources department that can take charge of managing the recruitment and training of apprentices. Indeed, interviewees' observed impression was that the apprenticeship system is hard to navigate, especially for a small organisation without a dedicated HR department. As one put it, the paperwork around apprenticeships is "horrendous, especially for a small company … it's a turnoff".[42]

In this context, it is worth considering briefly various possible ways of alleviating some of the burden on small employers, thereby encouraging them to take on apprentices. One possibility involves what is called 'over-training'. This involves large employers who currently offer high-quality apprenticeships playing a role in the training of more apprentices than they themselves require to meet their own anticipated needs, with the extra apprentices being employed from the outset of their apprenticeship by other firms (often SMEs). The larger firm will typically manage the training and assessment of the apprentices, using its own apprentice managers, instructors and assessors to do so. It may also provide some of the on-the-job training itself, especially if it has its own training facilities (such as a dedicated training workshop for the development of basic engineering skills). In this way, the SMEs that have their apprentices managed in this way can gain access to a more experienced, and effective, way of managing and training their apprentices than they themselves could provide on their own. Moreover, the large employers that offer such over-training do not do so as a charitable act, but rather because they expect to benefit from doing so, for one of two reasons: either because the government funding and fees they gain from over-training help them to cover some of the fixed costs of running their own apprenticeship schemes; or because, by training apprentices for firms in their supply chain, they stand to gain from having better quality, and /or more reliable, input supplies. Several large employers in UK advanced manufacturing already engage in over-training, and two of the larger manufacturers visited for this study suggested that they too might be interested in following suit (Lewis 2013c, 2014c; cf. HM Government 2015a: 24).

A second possibility involves what are called Group Training Associations. These organisations, some of which have been established for many years, are not-for-profit bodies whose goal is to facilitate cooperation between employers concerning various aspects of training, including: standard-setting; the development

42 For similar observations, see TBR (2016: 45).

of curricula; the recruitment and selection of trainees; and the actual delivery of training (including the provision of facilities and instructors, the management of training, and the assessment of certification of knowledge and skills) (Gospel and Foreman 2006, Cooney and Gospel 2008). In this way, GTAs promise to alleviate the administrative burden falling on employers who participate in apprenticeship training. Some employers in the chemical industry, for example, take apprentices via GTAs (Lewis 2013a: 27-28), while there are proposals for the SIP to form a GTA whose member organisations will be drawn from the science-based industries, including industrial biotechnology (SIP 2016; also see HM Government 2015a: 26).

Of course, none of the solutions to the various difficulties associated with apprenticeship training described above can be a universal cure (cf. UKCES 2015: 12). On the contrary, the ideas sketched above are better thought of as elements in a portfolio of options, and the best approach to adopt will depend on the context in which it is to be applied.

SECTION 6 CONCLUSION

This section summarises this study's findings on the five questions posed in the Introduction to the report.

Q1: First, what is the size of the technician workforce in the UK? Is it expanding, contracting or remaining stable?
Technicians currently account for a relatively small share of the total workforce in industrial biotechnology. Even in manufacturing firms, where technician positions are most common, such roles account for less than 30% of the workforce, while the share is significantly lower in process development and research & development organisations. This reflects the fact that industrial biotechnology is an 'emerging' technology, many aspects and applications of which are still under development. Many of the organisations involved in industrial biotechnology are still involved in fundamental research and process development, rather than full-scale manufacturing, and are also relatively small, all of which factors mean that the need for technicians is smaller than in larger, more 'mature' industries. However, as industrial biotechnology develops, and more firms both expand their activities from R&D to process development and ultimately to full-scale manufacturing, and also increase in size, one would expect the share of technician roles in the workforce to increase, as those organisations will have more and more work of the kind carried out by technicians needing to be done. Consequently, both the absolute number of technician roles, and also their share in total employment, are expected to increase.

Q2: Second, in what roles are technicians employed in industrial biotechnology? What kinds and levels of skills and qualification do those technicians need?
The main roles filled by the technicians who work in industrial biotechnology are as follows: laboratory and quality control technician; engineering maintenance technician; and manufacturing technician. Laboratory and quality control technicians typically need Level 3 skills and qualifications in subjects such as Laboratory and Related Technical Activities, while maintenance engineers are usually required to have Level 3 or Level 4 qualifications in mechanical, electrical, or control and instrumentation engineering. Two broad kinds of manufacturing technician may be distinguished. In large-scale industrial plants, manufacturing technicians are typically qualified to Level 3 in subjects that emphasise process operations and process engineering skills (e.g. City & Guilds Level 3 in Chemical Process Operations). In organisations that manufacture using laboratory and/or cleanroom-type facilities, manufacturing technicians tend to be qualified to Level 4/5 in subjects that place more emphasis on science and laboratory skills (e.g. HNC in Applied Biology or Higher Apprenticeships in Applied Bioscience Technology).

Q3: Third, how do employers in industrial biotechnology fill technician roles?
In practice, in the past, most laboratory technician roles have been filled by over-qualified graduates. This is because there is a plentiful supply of bio-science graduates being produced by British universities, which means that they can be hired to fill laboratory technician posts at relatively low wages. However, the use of such graduates can give rise to difficulties: they often lack practical skills; and they frequently become dissatisfied with their low wages they earn, and the routine work their job entails, and so leave their employer after only a relatively short period of time. Recently, frustration with the deficient practical skills, and limited loyalty, of such graduates has encouraged more employers to turn to apprenticeship training to fill laboratory technician positions.

Organisations have used a mixture of recruitment and apprenticeship training to fill their maintenance engineering positions. Apprenticeship has been, and continues to be, especially important in the case of control and instrumentation technicians, who are very hard to recruit from the external labour market.

The most common way for employers to obtain manufacturing technicians has been by hiring people who have already received significant levels of education and training outside industrial biotechnology, and then providing them with additional ('top-up') training to equip them with the specific skills and knowledge required for industrial biotechnology (a 'recruitment-and-top-up-training' approach). More recently, however, there has been an increase in interest in apprenticeship training, driven principally by the need for employers to obtain skilled manufacturing technicians in the face of continued recruitment difficulties.

Q4: Fourth, are organisations in industrial biotechnology suffering any skill shortages at the technician level?

There are two main areas where there are shortages of technicians. First, employers find it difficult to recruit experienced, IB-ready manufacturing technicians from the external labour market. This reflects two factors: industrial biotechnology is a relatively young field, so there has not been time to develop a pool of workers who have learned their trade in it; and industrial biotechnology is expanding, both because new firms are being set up, and also because more and more organisations are increasing the scale of their operations to the point where they find it worthwhile to employ dedicated manufacturing technicians. Second, there is also a scarcity of control and instrumentation engineers. Far from being confined to industrial biotechnology, this is a problem that is being experienced by several industries. In both cases, employers are responding to the difficulty of hiring suitable workers by turning to in-house training, including apprenticeships.

Q5: What should be done to help employers in industrial biotechnology acquire technicians?

Some organisations that currently take apprentices, or are thinking seriously about doing so, have found it difficult to find a local college or university willing to offer the off-the-job course through which apprentices acquire the technical knowledge that underpins their practical skills. The reason lies in the 'tyranny of small numbers', that is to say the fact that the total number of students wanting to take the courses in question in the relevant geographical area is too small to make it worthwhile for the relevant colleges to offer them, given the prevailing funding regime. In order to overcome this difficulty, it is necessary to aggregate the demand for training across employers, so that the number of trainees exceeds the minimum required to make it worthwhile for providers to offer training, and also to reduce the risk faced by potential training providers.

One way to do so is to share as much as possible technician training for industrial biotechnology with training for other process- and science-based industries, for example by drawing on existing provision for chemical process operators (with the addition of some modules dedicated to industrial biotechnology). Ways of ensuring that there is sufficient demand to entice providers into offering the industrial biotechnology-specific parts of the training include the following.

- Develop only a small number of centres of excellence that offer the training, located in areas where there is a significant concentration of IB employers.
- These centres should offer training via distance learning, supplemented by periodic residential courses or stints of block release, in order to extend their reach beyond the area in which they are located. The availability of such distance learning options need to be widely publicised.
- At least some of the relevant training courses should be developed so as to 'double up' as CPD modules for more established workers, further increasing demand.
- One way of reducing the risk faced by potential training providers is to utilise existing facilities, which are also used for purposes other than training (e.g. process development organisations such as Catapult centres). This will help to reduce both the size, and the riskiness, of the investment required to set up a training programme. Another advantage of such facilities as the locus for training is that doing so should also help to ensure that training programmes and syllabuses are kept up to date and thereby remain attuned to the needs of industry.

APPENDIX 1 APPRENTICESHIP STANDARD – LABORATORY TECHNICIAN[43]

Occupation – Laboratory Technician

Level - 3

Duration - Minimum of 18 months, typically 24 months duration.

Occupational profile
Laboratory technicians work in a wide range of organisations, including but not exclusively, chemical, primary and secondary pharmaceutical, biotechnology, formulated products, nuclear companies; and analytical science services. A laboratory technician may carry out both routine and one-off laboratory testing and perform a variety of technical support functions across the organisation. In any context working safety and ethically is paramount and many companies operate under highly regulated conditions because of the need to control the quality and safety of products, for example medicines. Laboratory technicians are expected to work both individually and as part of a laboratory team. They are able to work with minimum supervision, taking responsibility for the quality and accuracy of the work that is undertaken. They are proactive in finding solutions to problems and identifying areas for improving the business.

Occupational Skills & Knowledge
A laboratory technician can:

1. Work safely in a laboratory, maintaining excellent housekeeping whilst following appropriate safety, environment and risk management systems.
2. Understand and follow quality procedures to meet the requirements of quality standards relevant to the workplace.
3. Understand the internal and external regulatory environment pertinent to the sector and the employer and comply with regulations proficiently.
4. Prepare for laboratory tasks using the appropriate scientific techniques, procedures and methods.
5. Perform laboratory tasks following specified methodologies, such as Standard Operating Procedures.
6. Demonstrate technical competence in the use of specified instrumentation and laboratory equipment, including calibration where required.
7. Produce reliable, accurate data and keep accurate records of laboratory work undertaken and results.
8. Analyse, interpret and evaluate data and identify results requiring further investigation seeking advice of senior colleagues as appropriate.
9. Understand and apply statistical techniques for data presentation.
10. Communicate scientific information appropriately, including the use of Laboratory Information Management systems, either digital or paper based.
11. Recognise problems and apply appropriate scientific methods to identify

43 See www.gov.uk/government/uploads/system/uploads/attachment_data/file/448943/LIFE_AND_INDUSTRIAL_SCIENCES_Laboratory_Technician.pdf (made available via the terms of the Open Government Licence: www.nationalarchives.gov.uk/doc/open-government-licence/version/3).

causes and achieve solutions.

12. Participate in continuous performance improvement.
13. Develop and apply theoretical knowledge of relevant science and technology required for the sector & job role.
14. Understand the business environment in which the company operates including personal role within the organisation, ethical practice and codes of conduct.

Behaviours

15. A laboratory technician also demonstrates the required attitudes, behaviours and interpersonal skills associated with the professional workplace including:

- communicate effectively using a full range of skills: speaking; listening; writing; body language; presentation
- work and interact effectively within a team
- work independently and take responsibility for initiating and completing tasks
- understand impact of work on others, especially where related to diversity and equality
- time management and ability to complete work to schedule
- ability to handle change and respond to change management processes.

Qualifications

Apprentices without a level 2 English and mathematics will need to achieve this level prior to completion of their apprenticeship.

Apprentices must complete a level 3 or 4 qualification in a science or technology discipline relevant to their occupation, which is recognised for professional registration by RSciTech, prior to completing the end-point assessment. Example qualifications are detailed in the assessment plan for this standard.

Link to professional registration

The apprenticeship is recognised by the relevant professional bodies at Registered Science Technician (RSciTech) level, for which there is a requirement that the technician will participate in subsequent continuing professional development on completion of the apprenticeship.

Review date - June 2018

APPENDIX 2 APPRENTICESHIP STANDARD – SCIENCE INDUSTRY MAINTENANCE TECHNICIAN[44]

Occupation - Science Industry Maintenance Technician (Mechanical, Electrical, Instrumentation)

Level - 3

Duration of Apprenticeship - Minimum of 36 months, average 42 months duration.

Role profile
A science industry maintenance technician contributes to the fault free and safe operation of science industry plant by the installation, maintenance, testing and repair of mechanical, electrical equipment and instrumentation. They will be proactive in finding solutions to problems and identifying areas for improving their work environment. As well as core engineering skills, maintenance technicians need to understand and follow working practices that are specific to the safety critical science industry. They may work in varied conditions including using specialist safety equipment, shift work and on sites running 365 day operations. They will be expected to work both individually and as part of a maintenance team. They will be able to work with minimum supervision, taking responsibility for the quality and accuracy of the work they undertake. They may be part of in house maintenance teams or engineering maintenance contractor teams who work for different companies across the science industry.

Science industry maintenance technicians work in a wide range of companies, including, but not exclusively, chemical, petrochemical, polymer, primary and secondary pharmaceutical, biotechnology, formulated products, engineering and nuclear manufacturing. In either case employers are subject to inspection by the regulator for their industry, for example, Health and Safety Executive or Medicines and Healthcare Products Regulatory Agency. As companies operate under highly regulated conditions a premium is placed on appropriate attitudes and behaviours to ensure apprentices comply with organisational safety and regulatory requirements at all times.

Occupational Skills & Knowledge
At the end of the apprenticeship the apprentice will be able to:

1. Work safely in a science industry environment, understanding personal responsibility for Health, Safety, Environment and Security and principles of risk management.
2. Understand and follow quality procedures to meet the requirements of quality standards relevant to the workplace.
3. Understand the internal and external regulatory environment pertinent to the sector and the sponsoring company and comply with regulations proficiently whilst keeping up to date with any changes.
4. Understand and apply problem solving techniques.
5. Participate in continuous performance improvement.
6. Understand the business environment in which the company operates including personal role within the organisation, ethical practice and codes of conduct.

44 See www.gov.uk/government/uploads/system/uploads/attachment_data/file/384224/LIFE_SCIENCES_AND_INDUSTRIAL_SCIENCES_-_Science_Industry_Maintenance_Technician_-_Final_081214.pdf (made available via the terms of the Open Government Licence: www.nationalarchives.gov.uk/doc/open-government-licence/version/3).

7. Safely use all necessary equipment, following the appropriate engineering techniques, procedures and methods of relevance to complete the maintenance activity.
8. Prepare the work area for maintenance of plant, systems or components.
9. Carry out planned routine and non-routine maintenance activities, effectively, efficiently and safely.
10. Understand and apply the practices and procedures for planning to maintain systems and equipment, relevant to a single specialist discipline or a number of disciplines (mechanical, electrical, instrumentation) as required by the job role whilst following applicable codes and standards.
11. Understand and apply techniques to identify faults in plants, systems and components to achieve satisfactory solutions.
12. Reinstate the work area after completing the maintenance of plant, systems and components.
13. Conduct safe and effective exchange of plant and equipment to others and accept and confirm responsibility for the plant and equipment within the work area.
14. Manufacture or assemble components within skill set.
15. Understand how to identify obsolescence and end-of-life issues.
16. Understand and apply information extracted from engineering drawings, specification diagrams and maintenance manuals and/or computer database systems including accurate data input.
17. Understand and apply technical knowledge relevant to a single specialist discipline or a number of disciplines (mechanical, electrical, instrumentation) as required by the job role.
18. Develop and apply theoretical knowledge of engineering and its application to the required sector & job role. This should be acquired through a qualification set at level 3 (or above) that is approved by a licensed professional engineering institution.

Behaviours

19. The apprentice must also demonstrate the required attitudes, behaviours and interpersonal skills associated with the professional workplace including:

- communicate effectively using a full range of skills: speaking; listening; writing; body language; presentation
- work and interact effectively within a team and other groups as required
- work independently and proactively take responsibility for initiating and completing tasks
- understand impact of work on others, especially where related to diversity and equality
- excellent time management and ability to complete work to schedule
- ability to handle change and respond to change management processes in a positive manner
- pursuing excellence in line with organisational norms and values
- demonstrate a can do attitude and willingness to operate flexibly to meet business demands.

Entry Requirements

Individual employers will set the selection criteria for their apprentices. Most candidates will have achieved grade C or above in English and Maths and a STEM-related subject at Level 2 prior to commencement of apprenticeship.

English & Mathematics

The apprentice will have a depth and breadth of English and mathematics that allow them to operate successfully within their role. This may be met through entry criteria determined by the employer or qualifications and training within the apprenticeship. However, on completion all apprentices will have minimum level 2 qualifications in English and mathematics. Some employers may mandate training or qualifications at level 3 in English and/or mathematics.

Professional Recognition

This standard aligns to the core engineering skills required for similar occupations in other industries. This Standard has been designed to deliver sufficient Underpinning Knowledge and Understanding (UKU) and allow apprentices sufficient experiential, work based learning opportunities to satisfy the requirements for Professional Registration as Engineering Technician (EngTech) as defined by the UK Standard for Professional Engineering Competence (UK-SPEC).

Learning & Training

Employers will compile an Apprenticeship training plan that describes the training their apprentice will need to meet the standard. It may include a mixture of external and internal training that will ensure the apprentice is fully competent by the end of their programme and ready to take the assessment. It will show when each area of the standard must be acquired and assessed and which areas may be acquired off the job. An apprentice will receive a minimum of 20% of their training away from their day-to-day job. The apprentice will gain transferable core skills and knowledge. In addition they will gain skills specific to the job role and the working practices of their place of employment. The requirements of the apprenticeship are designed to offer stretch and progression.

Review Date: This Apprenticeship standard will be reviewed by employers in September 2017.

APPENDIX 3 APPRENTICESHIP STANDARD – SCIENCE MANUFACTURING TECHNICIAN[45]

Occupation - Science Manufacturing Technician

Level - 3

Duration - Minimum of 18 months, typically 30 months duration.

Occupational profile
Science manufacturing technicians work in a wide range of companies, including, but not exclusively, chemical, primary and secondary pharmaceutical, biotechnology, formulated products and nuclear manufacturing. A science manufacturing technician will operate the systems and equipment, involved in the production of products. They may work in varied conditions including wearing specialist safety equipment, shift work and on sites running 365 day operations. Many companies operate under highly regulated conditions and a premium is placed on appropriate attitudes and behaviours to ensure employees comply with organisational safety and regulatory requirements.

Science manufacturing technicians are expected to work both individually and as part of a manufacturing team. They are able to work with minimum supervision, taking responsibility for the quality and accuracy of the work they undertake. They are proactive in finding solutions to problems and identifying areas for improving their work environment.

Occupational Skills & Knowledge
Science manufacturing technicians are able to:

1. Both independently and within a team start-up a manufacturing batch or continuous process in line with appropriate Standard Operating Procedures, understanding the principles of operation.
2. Both independently and within a team operate a manufacturing batch or continuous process in line with appropriate Standard Operating Procedures, understanding the principles of operation.
3. Both independently and within a team shut down/complete a run of the manufacturing batch or continuous process in line with appropriate Standard Operating Procedures, understanding the principles of operation.
4. Work safely in a science manufacturing environment, understanding personal responsibility for Health, Safety and the Environment and principles of risk management
5. Understand and follow quality procedures to meet the requirements of quality standards relevant to the workplace.
6. Understand the internal and external regulatory environment pertinent to the sector and the employer and comply with regulations proficiently.
7. Control and monitor a process or plant and equipment, effectively, efficiently and securely, and resolve problems or correct abnormal conditions.

45 See www.gov.uk/government/uploads/system/uploads/attachment_data/file/448968/LIFE_AND_INDUSTRIAL_SCIENCES_Science_Manufacturing_Technician.pdf (made available via the terms of the Open Government Licence: www.nationalarchives.gov.uk/doc/open-government-licence/version/3).

8. Complete documentation relevant to the manufacturing process including relevant calculations.
9. Understand the business environment in which the company operates including personal role within the organisation, ethical practice and codes of conduct.
10. Participate in continuous performance improvement.
11. Develop and apply theoretical knowledge of relevant science and technology and its application to the required sector & job role.

Behaviours

12. Science manufacturing technicians are able to demonstrate the required attitudes, behaviours and interpersonal skills associated with the professional workplace including:

- communicate effectively using a full range of skills: speaking; listening; writing; body language; presentation
- work and interact effectively within a team
- work independently and take responsibility for initiating and completing tasks
- understand impact of work on others, especially where related to diversity and equality
- time management and ability to complete work to schedule
- ability to handle change and respond to change management processes.

Qualifications

Apprentices without level 2 English and mathematics will need to achieve this level prior to completion of their apprenticeship.

Apprentices must complete a level 3 or 4 qualification in a science or technology discipline relevant to their occupation, which is recognised for professional registration by RSciTech or Eng Tech, prior to completing the apprenticeship's end-point assessment. Example qualifications are detailed on the assessment plan for this standard.

Link to professional registration

The standard is recognised by the relevant professional bodies at Registered Science Technician (RSciTech) level, for which there is a requirement that the technician will participate in subsequent continuing professional development on completion of the apprenticeship.

This standard meets the professional standards of the Engineering Council for registration as an Engineering Technician (EngTech). Registration is subject to candidates successfully completing the appropriate learning, developing the appropriate competence, and undergoing professional review.

Review date – June 2018

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