Learning and Skills Improvement Services

NANOTECHNOLOGY FEASIBILITY STUDY RECOMMENDATION REPORT

Newham College of Further Education

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Revision Sheet

Version No.	Date	Revision Description
V.1.0	21/05/12	1st Draft - Feasibility Report
V 2.0	01/07/12	2nd Draft - Feasibility Report
V 3.0	09/01/13	3rd Draft – Feasibility Report

NANOTECHNOLOGY FEASIBILITY STUDY REPORT

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Nanotechnology Feasibility Study

Newham College has been funded by LSIS, Learning & Skills Improvement Service to manage this project; 'Nanotechnology Feasibility Study' and produce a recommendation report.

The aim of this project is to bring together providers and key stakeholders including Sector Skills Councils (SSCs) and the Institute of Nanotechnology (IoN), awarding bodies and delivery partners to explore the feasibility of one or both of the given options;

- Develop standalone unit/s in Nanotechnology that would fit into existing QCF qualifications and in particular Apprenticeship frameworks across a range of industry sectors or
- Create a new Nanotechnology Apprenticeship framework

This project has focused on three industry sectors that overlap in terms of skills and technologies, and where majority of Nanotechnology based products are commercially available and where the future use of these technologies is eminent for environmental benefits, product benefits and cost savings. The selected industry sectors are;

1. Construction
2. Facilities Management; Housing, Property, Planning, Cleaning and Parking
3. Energy & Utilities; Gas, Power, Waste Management and Water Industries

The Nanotechnology/ RFID Discovery Lab based at Newham College has been involved with the delivery of nanotechnology introduction and hands-on application training courses for the last 4 years and has gained much experience in this area of science at Further Education level. Newham College has worked closely with The Institute of nanotechnology (IoN) on an ERDF funded project 'Showcasing Innovation' where we trained 120 small and medium sized businesses in the use of nanotechnology-based products and applications, and we have jointly delivered a conference on 'Smart Buildings for the Future'.

The listed partners in the table below formed the 'Project Working Group' and all decisions were taken jointly. Not all partners were able to attend meeting in person, however their verbal and email contributions were noted.

List of stakeholders & partners

	Organisation
LSIS	LSIS Associate
Host College	Newham College
	College's Apprenticeship Unit
ION	Institute of Nanotechnology
SSCs	SEMTA
	Construction Skills
	EU skills
	Proskills
	Cogent
Training Providers	Bedford College
	College of North West London
Awarding Body	Edexcel

Introduction

This feasibility report has been prepared to take account of the rapid developments taking place in the commercial application of nanotechnologies and the growing availability of consumer and professional products incorporating nanotechnologies or nanomaterials.

The report provides an overview of some of the nanotechnology-based products becoming available in three industry sectors, namely

- construction
- facilities management
- energy and utilities

However, as nanotechnologies are also rapidly impacting other industry sectors, some implications may be additionally drawn as to the need for assessing the implementation of a nanotechnology core module or sector-specific training modules in those sectors.

It draws some conclusions as to the likely training need for higher-level apprentices that these technological developments may bring in terms of theoretical and practical knowledge.
It also consider these potential training needs in the context of the UK government's recently published strategy for nanotechnologies **"UK Nanotechnology Strategy 2010".**

The report incorporates feedback from a number of selected companies and stakeholders on their perceived needs for the training of higher level apprentices in relation to nanotechnologies.

The final part of the feasibility report offers some suggestions as to the possible content of (a) core module(s) on nanotechnologies to be considered for incorporation into existing apprenticeship training programmes.

Methodology

The Nanotechnology Feasibility project was carried out in two phases.

- **Phase one** - focused on research and worked with listed stakeholders to make educated decisions on how to proceed with part two of the project
- **Phase two** - focused on the draft development of qualification/s

Phase 1 – Feasibility Study

- Identify existing qualifications/ accreditations in Nanotechnology
- Identify the types of Nanotechnologies available in the named Industry sectors
- Identify the skills required to make use of these nanotechnologies
- Identify 'job roles' that would use the available Nanotechnologies within the named industry sectors
- Identify the skills gaps
- Explore with working group the feasibility of creating a new Nanotechnology apprenticeship or to create new units that could fit into the existing Apprenticeships for the named industry sectors
- Write a Feasibility report including all findings and recommendations

Phase 2 - New Nanotechnology accreditation/ units

Our research showed that currently only one level 4 unit exists in Nanotechnology and some science based subjects at GCSE and A' Level briefly mention Nanotechnology as part of the main program.

There is no other qualification available in this subject area as a separate and individual qualification or unit and this topic is not covered at QCF levels 1, 2 and 3 in any other existing UK curriculum including apprenticeship frameworks.

Our research identified the need for an optional knowledge based nanotechnology unit that would fit into existing Apprenticeship Frameworks for all three identified industry sectors.

The decision was taken to develop a level 3 Knowledge based Nanotechnology units. The developed unit covers core knowledge areas all three listed industry sectors and would also easily fit into Apprenticeship Frameworks for other industry sectors. *e.g. Industry sectors such as ICT, engineering, mechanics, electronics, manufacturing and others.*

What is nanotechnology?

Nanotechnology is a branch of science and engineering that studies and exploits the unique behavior of materials at a size scale of approximately 1 to 100nm (nanometers). One nanometre (1nm) is 10^{-9} m (one billionth of a metre or about 10 000th the diameter of a human hair). The British Standards Institution (BSI) defines the nanoscale as being *"where one or more dimensions are in the order of 100nm or less"*, so a nanomaterial may be a surface or other structure as well as a particle.

Nanotechnology is also usually taken to mean materials or surfaces that are *intentionally altered or manipulated* at the nanoscale (1nm to +/- 100nm) to give *new properties*. These novel properties at the nanoscale can frequently be harnessed to provide increased functionality and performance to materials and products.

General economic forecasts for nanotechnology-enabled products

Early market forecasts for the impact of nanotechnologies were somewhat aggressive and optimistic. The growth of nanotechnology's now exhibits a more evolutionary pattern that was previously predicted and the economic downturn since 2008 has caused some downward adjustment in earlier market forecasts. Lux Research's 2009 global nanotechnology market forecast was decreased by 4% as compared to its 2007 estimates but, nevertheless, still predicts a global market for nanotechnology-enabled products of $2.5 trillion by 2015.

Policymakers are often especially interested in the economic development effects of new technologies, such as nanotechnologies and their impact on low-carbon products and technologies, including impacts on jobs and wages. According to a 2012 OECD paper, it is widely expected that employment will be generated through research, manufacturing, delivery, use, and maintenance related to green nanotechnology products and processes, and associated industries and services, although predicting the number of new jobs is difficult. Existing workers may shift into green nanotechnology activities as conventional products are replaced, although the metrics for determining such activities are complex.

Political background to nanotechnologies and training

UK Nanotechnology Strategy 2010

The UK Nanotechnology Strategy, published by the UK government in 2010 stated that:

- nanotechnologies are important to the future of the UK because of their potential to improve many types of consumer products;
- nanotechnologies could also help us address universal challenges such as global warming and food sustainability; and
- the worldwide transition towards the greater use of nanotechnologies is a significant economic opportunity for the UK. The global market in nano-enabled products is expected to grow from $2.3 billion in 2007 to $81 billion by 20151.To fully meet this opportunity, the UK will need to build upon its existing commercial strengths in nanotechnologies.
- the UK is ranked third in the world, after the US and Germany, when it comes to the number of nanotechnologies companies operating. The European Commission completed a study of the economic development of nanoscale technology in 2006. According to this the UK was:
    - fourth in terms of number of patents applied for in the area of nanotechnologies, after the US, Japan, and Germany;
    - very strong in nano-optics, placed third after the US and Japan; and
    - fourth on nanoscale materials after the US, Japan and Germany.

A survey, using data from the Nanotechnology Knowledge Transfer Network (KTN), estimated that there were around 220 companies in the UK for which nanotechnologies makes up a significant portion of their business. However, the government Mini Innovation and Growth Team (Mini-IGT) involved considered that this figure was conservative and might only represent a fraction of the true number because the involvement of many organisations is somewhat removed from the nanomaterial itself. For example a manufacturer of windows might use a water-resistant coating containing a nanomaterial purchased from a supplier without considering themselves to be a nanotechnology company.

In its subsequent report *"Nanotechnology: a UK Industry View, 2010"*, the Mini-ITG went on to conclude:

"People with sufficient skills in this high-value, high-skilled, knowledge-based market are essential to drive innovation and sustain the development of nanotechnologies. Currently the two most important barriers to the supply of skilled people are the lack of adequate training programmes and the high cost of those that do exist"

In the section of the report entitled "Raising Awareness and Education" (Action 2.9) the UK Nanotechnology Strategy states:

"The skill requirements of the nanotechnologies sector will be addressed through a range of complementary Government policies, as outlined in Government's framework for higher education "Skills for Growth" (www.bis.gov.uk/skillsforgrowth) and "Higher Ambitions" (www.bis.gov.uk/higherambitions):

- *35,000 additional advanced apprenticeships available for 19-30 year olds over the next two years to meet technical skills needs in advanced manufacturing sectors;*
- *Measures to make the adult skills and higher education systems more responsive to the needs of employers;*
- *Resources for skills focused on areas of the economy which can do the most to drive growth and jobs, including science, technology, engineering and mathematics (STEM) at higher education level;*
- *Work with the relevant sector skills councils and UK Commission for Employment and Skills to identify longer term skills needs in advanced sectors and ways in which these needs can be addressed;*
- *RDAs will address skills supply for growth sectors, such as nanotechnologies, in their skills strategies, so that skills provision is responsive to regional strategic economic needs.*

International initiatives

Germany

As long ago as May 2004, the Times Higher Education Supplement reported on initiatives in Germany to launch an "apprenticeship offensive", where a particular potential for apprenticeships in the growth areas of microsystems technology, nanotechnology and biotechnology was identified. The German Minister for Education and Research, Edelgard Bulmahn, underlined the urgency of the situation, referring to the growing demand for skilled workers and technicians, saying *"The experts have all agreed that, without effective efforts in the area of training, by the year 2015, in the age group 35 to 45, we will have a shortage of 3.5 million skilled workers."*
http://www.timeshighereducation.co.uk/story.asp?storyCode=188572&sectioncode=26

Switzerland

In Switzerland, the Innovation Society, St.Gallen, with the support of several Swiss Federal Offices (OPET, FOEN, FOAG) launched the "Swiss Nano Cube" project in 2009 together with the Swiss Federal Institute for Vocational Education and Training (SFIVET) and partners from industry. The Swiss Nano-Cube (www.swissnanocube.ch) is an interactive knowledge and education gateway for micro and nanotechnology for use in vocational and grammar schools. The goal of Swiss Nano-Cube is to awaken interest for technological and natural scientific topics among young people, thereby imparting knowledge about practice-relevant knowledge of nanotechnology for apprentices. Although being a key technology with a huge potential and diverse application opportunities, teaching material and education and formation offers for nanotechnology are scarce. Many teachers have not dealt with nanotechnology in their education. The Swiss Nano-Cube project is therefore intended to bridge this gap.
http://www.innovationsgesellschaft.ch/index.php?section=news&cmd=details&newsid=603&teaserId=4&setLang=2

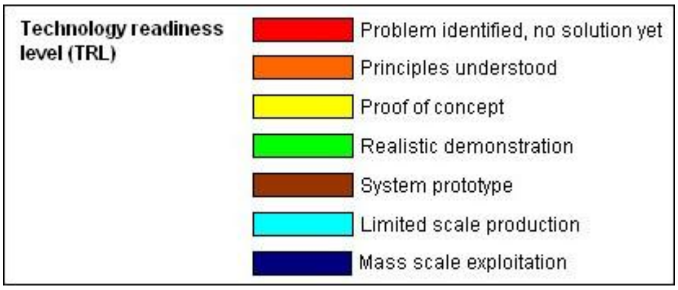
United States

In the United States the International Association of Nanotechnology, in partnership with the California Institute for Technology and the Clean Tech Institute, offers professional training courses, including apprentice programmes, in clean technology engineering (although in this case the concept of an "apprentice" is different with the prerequisite of a suitable first degree required).

Overview of some nanotechnology-enabled products for identified industry sectors

This section provides a brief description of some of the nanotechnology-enabled products listed in table 1 and is intended to show the breadth and potential impact of nanotechnology-enabled products in the three sectors. It draws some conclusions concerning the need for knowledge and training amongst apprentices likely to encounter those products. The descriptions and examples of products are not intended to be exhaustive as new innovations are continually reaching the market. Some of these products may be common to more than one sector.

Indications of technology readiness levels (TRL) are given according to the following key:



In some cases, more than one TRL may be shown as there may be a number of nano-based solutions emerging for a specific product group, e.g. ranging from examples at proof-of-concept stage to mass-market exploitation. Equally, a manufacturer may have released a novel product to local market with a view to extending it to the mass market. TRLs that have already been met are coloured in grey in the figures that follow.

The examples that follow represent a selection of emerging nanotechnology-enabled products that an apprentice may reasonably expect to encounter in the construction, facilities management and utilities sectors, as those sectors are the primary focus of this feasibility report. Other products, based on the application of nanotechnologies, are also now increasingly appearing in the market in other industry sectors such as aerospace, automotive engineering, textiles and fashion, healthcare and information technology. This report may then be taken to indicate the need for similar feasibility studies on developing sector-specific nanotechnology training in those sectors and apprentice stories later in this report indicate the importance of emerging technologies in other sectors.

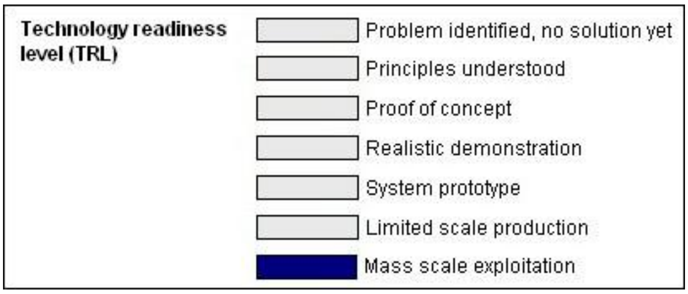
Where information is available, indications concerning the economic impacts of these different nano-enabled products have been included.

Nano-concrete and cement

The application of silica nanoparticles has enabled cement and concrete products to be developed that are significantly lighter than conventional concrete (up to 40% less dense), have improved viscosity and rheology, are lower in porosity and therefore have lower permeability and better wear, have good strength characteristics, can enable up to a 12% reduction in materials, and which can also offer other economic benefits such as reduction in operational time.

Other nanomaterials can also be added to produce products such as concrete paving slabs that can photocatalyse nitrogen oxides and other urban pollutants.

Because of the differences in formulation, quantities, use of additives and working from traditional concrete, there are training needs associated with these novel materials.



Economic impact

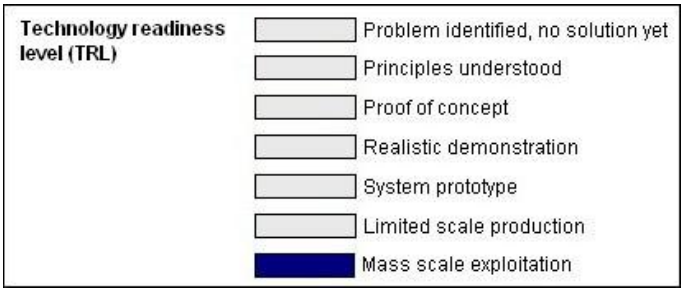
With a production volume of more than 14 billion tons per year concrete is the most widely-used material on earth. Nano-enhanced cement has not yet become a construction standard. Since most benefits are environmental, the likelihood of increased legislation aimed at lowering the carbon footprint of manufacturing (around 5% of global CO2 emissions are claimed to originate from cement and concrete production) and other benefits such as savings in materials (e.g. an estimated saving in cement of around 35-45%) and in operational time will be likely to play an important role in increasing market penetration. According to data presented at a 2007 US workshop sponsored by the US National Concrete Pavement Technology Center and the National Science Foundation, one significant need in concrete construction is to significantly increase reliability. It is estimated that up to 10% of concrete placed in a given year fails prematurely or is below standard from the beginning. Considering that concrete construction is a US$700 billion dollar industry worldwide, even a small reduction in the number of problems, many of which can be addressed by use of nanomaterials and nanotechnology, would amount to significant economic savings and performance benefits

Self-cleaning glass and other nanoscale coatings for glass

A number of companies are producing glass for construction use which is self-cleaning. The leading UK-based glass manufacturer, Pilkington PLC, has developed a self-cleaning glass called Pilkington Activ™ which has an incorporated hard, dual action surface coating with hydrophilic and photocatalytic properties, based on a 15nm (nanometre) layer of titanium dioxide. Organic and inorganic deposits on the surface of the glass are broken down by sunlight through photocatalysis and, because the surface is hydrophobic, are readily washed away by rain or by simple hosing. The effects are continuous and last the lifetime of the glass.

Because of the need to protect the coating, special care is required during the processing, handling and installation of the glass.

Other coatings based on nanomaterials are available for glass that can, for example block UV radiation from outside, block heat radiation to the exterior from the inside of a building or reduce condensation.



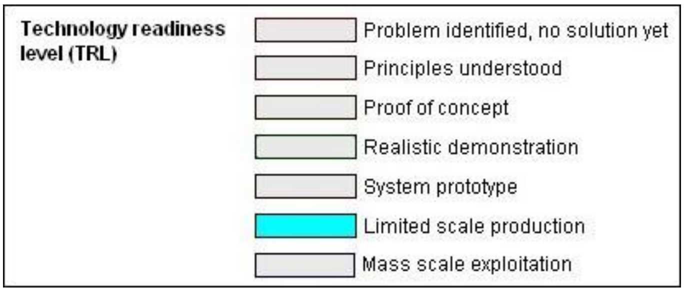
Economic impacts

The market for the coating of flat glass for low emissivity was estimated at US$1 billion in 2010 (Bax, 2010). The market for electrochromatic glass is expected to reach US$218.3 million in 2013.

Insulation materials, e.g. aerogels and nanofoams

There are a number of novel insulating materials based on nanomaterials which have very high specific insulative performance and which can achieve results equivalent or superior to traditional products but with substantially lower thickness. Examples include insulation materials based on so-called aerogels and nano-foams.

Because of the much reduced bulk of these materials they are highly suitable for renovation and retrofitting projects, as well as for new builds, and, as such, are likely to be used by many apprentices working in these sectors as they are introduced to the wider market.



Economic impacts

Aerogels, in substitution for denser foam-based insulation, are estimated to comprise a US$646.3 million market by 2013, although their initial applications are expected to be as insulation in gas and oil pipes, medical devices, and aerospace rather than insulation materials in building construction. The higher current cost of these materials, relative to conventional building materials, may be a factor in initial market uptake by the construction industry, although they ultimately promise higher levels of performance.

Nanostructured self-cleaning surfaces and applied nano- surface treatments

Nanotechnology has been applied in a number of ways to produce surface that are self-cleaning. Glass with an incorporated self-cleaning layer has already been described above. Another strategy has to been to follow a *biomimetic* approach. The leaves of a number of plants, notably those of the lotus flower (*Nelumbo* spp.) exhibit a so-called lotus effect or very high level of water repellence (superhydrophobicity). Dirt particles are picked up by water droplets and, due to a complex micro- and nanoscopic architecture of the leaf surface, this water simply rolls off in droplets and does not adhere to the surface. *Biomimetic* approaches attempt to reproduce these naturally-evolved characteristics in man-made materials, typically by altering the surface topography or other surface architecture of the material. Such materials are already being used in aeronautical engineering to reduce contamination and drag of surfaces and can also be applied in other sectors.

It is highly likely that the application of nanotechnology and nanomaterials will underpin future biomimetic approaches where designs evolved by nature are incorporated into man-made products. An overview of these principles together with some practical examples will be of value in higher-level apprentice training.

Self-cleaning properties can also be imparted to construction products by applying a variety of surface treatments based on the nanoscale properties of materials and it is likely that apprentices will work with or in proximity to these materials. Examples of commercialized products include transparent photocatalytic coatings based on titanium dioxide nanoparticles that can be used to coat masonry products, glass, tiles and facades to prevent the build-up of dirt, particularly in urban environments.

Technology readiness level (TRL)	Problem identified, no solution yet
	Principles understood
	Proof of concept
	Realistic demonstration
	System prototype
	Limited scale production
	Mass scale exploitation

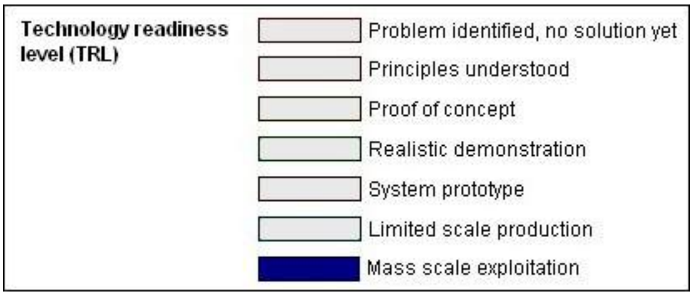
Sealants and adhesives

A number of nanomaterials are already added to adhesives and sealants, including:

- nanosilica: used as a thickening agent with thixotropic properties, i.e. it can become less viscous and flow under certain conditions
- nanoscale precipitated calcium carbonate: control of rheology, stiffness, impact resistance and weatherability
- silane-based products for sealing and waterproofing woods
- titanium dioxide: e.g. as a pigment

Nano-sealants typically contain silica or other ceramic nanoparticles, or a nanopolymer and organise themselves to form a coating and bond with the surface after application. They can be used to seal a wide range of materials, including metals, glass, ceramics, electronics, synthetic and natural materials. If the surface is smooth and non-absorbent, the nanoparticles combine with the surface, and repel any contaminants or liquids. If the treated surface is porous, the nanoparticles fill up the pores from the inside. Dirt, liquids or biological contaminants cannot then get into the surface and are simply repelled.

From a training perspective apprentices should know how these products work and offer benefits over other products as well as their mode of application and any special precautions required.



Economic impacts

This category of nano-enabled products was worth €1.9 billion to the European construction industry in 2009 and it is estimated that around 10% of adhesives and sealants contain nano-fillers.

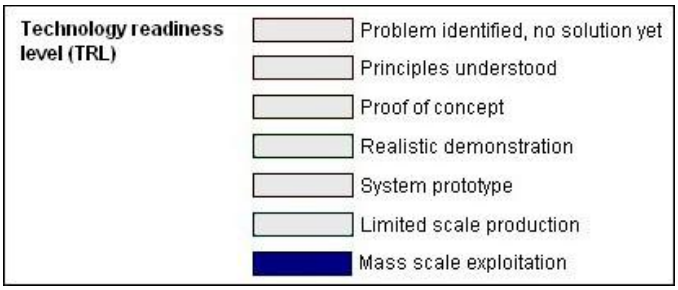
Paints and other applied protective coatings, e.g. wood treatments and anti-corrosion products

Paints are now a major application area for nanomaterials. Nanoscale titanium dioxide has been used for many years as a pigment in paints and to provide better optical and covering properties and, now, a variety of specialist paints are coming on to the market that utilise nanomaterials to provide a variety of useful characteristics. Examples include the use of nanosilver to produce paint that is antibacterial, the use of nanosilica in paints that can help regulate room temperature and prevent heat loss, the incorporation of ceramic nanoparticles to produce paints that are highly scratch-resistant and nanosilica-based anti-graffiti paints that prevent the graffiti layer sticking to the surface to be protected.

Anti-corrosion coatings are of importance where metals have to be protected in harsh environments, e.g. in offshore construction. There are many types of both metallic, e.g. galvanised, or painted, e.g. fusion-bonded epoxy-based, polypropylene-based, anti-corrosion coatings. Novel painted or sprayed products increasingly incorporate nanotechnology such as an inorganic nanoparticle matrix to provide a robust and durable surface.

Wood, unlike metals and concrete, is a biological material that presents its own set of characteristics and challenges in protection. It is, for example, heterogeneous, porous, biodegradable, sensitive to UV radiation and hygroscopic. Novel wood coatings and protection products may therefore incorporate a variety of nanomaterials to improve protection, e.g. aluminium oxide (hardness, abrasion- and scratch resistance), iron oxide (UV protection), silver (antimicrobial), titanium dioxide (UV protection, anti-microbial), zinc oxide (UV protection, anti-microbial) and silica (hardness, abrasion- and scratch-resistance, and waterproofing).

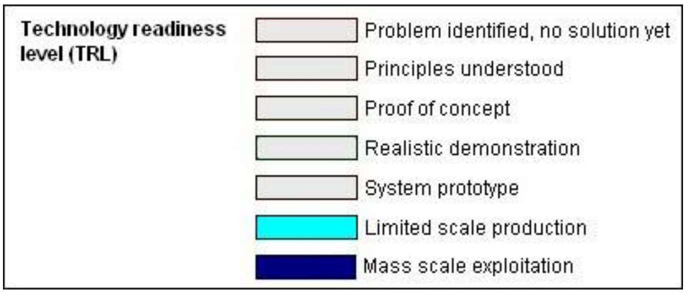
In terms of training, all of these products and processes are likely to be encountered by apprentices and have their own special needs and precautions in terms of preparation, application and maintenance.



Nanocomposites and reinforced polymers

A nanocomposite material is a solid combination of bulk matrix material such as a polymer and one or more nano-dimensional phases. The components differ in their properties due to dissimilarities in structure and chemistry. Nanocomposites differ from conventional composite materials mainly due to the very high surface to volume ratio of the reinforcing (nanoscale) phase. This large surface area means that a relatively small amount of nanoscale reinforcement can have a significant effect on the macroscale properties of the composite. Nanocomposites are found widely in nature, for example in the structure of bone. The mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the nanocomposite will differ from that of the component materials and can provide advantages over the parent materials such as strength, lightness, durability and other characteristics. Nanocomposites are widely used in the aeronautical, automotive and other engineering sectors and are beginning to impact the construction sector. There are potentially thousands of combinations of matrix materials and nanofillers available with a very wide range of physical and mechanical properties. Examples of nanocomposite construction products include PVC nanocomposites used in windows and doors, and in large diameter piping and other applications requiring rigidity, nanocomposites incorporating nanoclays for fireproofing, cellulose based nanocomposites in insulation and asphalt-based nanocomposite roofing.

In view of the increasing use of nanocomposites, training needs are envisaged that provide an overview of the properties, selection, use and maintenance of these materials.



Economic impacts

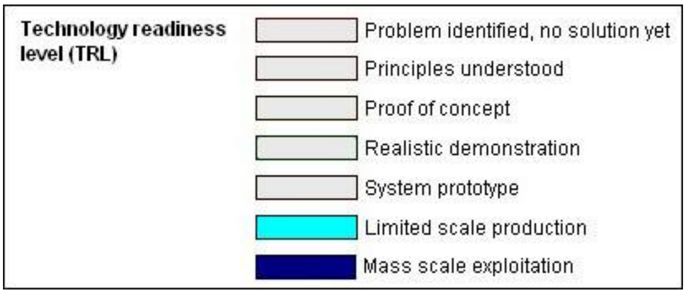
In 2011 the global consumption of nanocomposites was US$920 million and 138,389 metric tonnes (ObservatoryNano Briefing No. 30, March 2012). With a compound annual growth rate of 19% in unit terms and of 21% in value terms, the market for nanocomposites is predicted to grow to 333,043 metric tonnes with a value of about US$2.4 billion by 2016. While the majority of these nanocomposites are currently used in packing and automotive applications, applications in other sectors are also increasing due to the advantages nanocomposites offer over conventional materials.

Functionalised textiles

Nanomaterials can be incorporated into textiles in a variety of ways to provide them with novel or advantageous properties and it is also possible to change the surface characteristics of textiles, or the fibres that they are made from, at the nanoscale by novel processes such as low-temperature plasma treatments. Benefits that can be gained include imparting special self-cleaning abilities (e.g. by altering the hydrophobicity and hydrophilicity of the fabric surface), durability and wear resistance characteristics (e.g. by incorporating silica nanoparticles), resistance to microorganisms (e.g. by light (e.g. by incorporating nanoscale titanium dioxide) and integrating sensors and electronics into textiles (for example by using carbon nanotubes or other conducting nanomaterials).

Examples where such materials may be used in construction and in facilities management include geotextiles, linings, carpets, tiles and interior furnishings and decoration. In some cases, sensors may also be incorporated into such materials (e.g. pressure sensors and security sensors in "smart buildings").

While many nano-enhanced textiles will require few special training needs, others, e.g. those with embedded sensors or electronics, may require specialist knowledge in terms of installation or maintenance.



Economic impacts

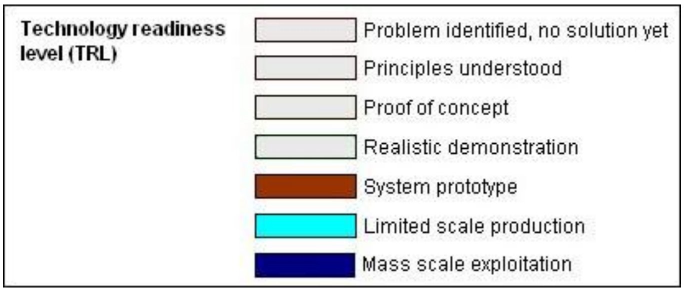
The current global market for technical textiles is around US $127 billion (23.77 million tonnes). It is currently estimated (ObservatoryNano Briefing No. 33, March 2012) that construction textiles amount to about 10% of the total technical textiles market, corresponding to about US $12.7 billion, with a growth rate) of around 5% per year.

Solar energy capture

Nanomaterials are underpinning the latest generation of solar energy capture systems. There are a number of forms of solar cell using different technologies, many of which are increasingly at the nanoscale, such as semiconductor junctions, thin film technologies, quantum dots (a type of nanocrystalline semiconductor), silicon nanostructures, polymer cells and dye-sensitised cells, all of which work by converting solar energy photovoltaically (hence the alternative term “photovoltaic cell”).

While early generation solar cells were limited in their efficiency, the latest, third generation, thin film devices, have a combination of theoretical 30-60% conversion efficiency, an ability to utilise sunlight at varying angles, and low cost materials and manufacturing processes. Other recent innovations include the development of flexible solar panels for buildings, portable rollable flexible solar panels that can be transported and stored for use. A further current area of research is into flexible energy-capturing and converting coatings based on nanotechnologies, that can be applied to the exterior surfaces of buildings and which, with the simultaneous application of modern battery technologies, enable the building itself to act as its own “power station”.

In terms of training, there will be needs for basic knowledge about how different solar energy capture systems work, how they combine with smart processors to utilise and store energy in electrical form and, in many cases, export excess energy to the national grid. From a practical point of view, there are clear training needs for the installation and maintenance of such systems.



Economic impacts

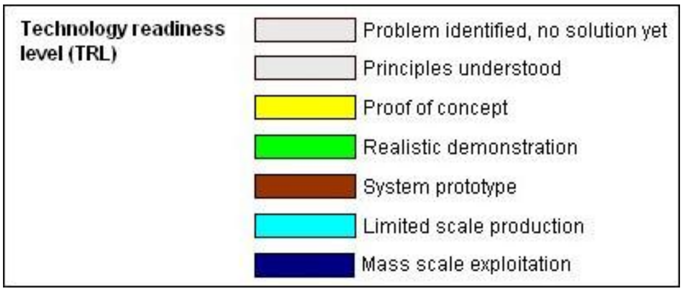
Nanotechnology-enabled solar cells and photovoltaic applications are frequently highlighted as potential growth markets. Lux Research’s (2007) estimate of the global market for nano-enabled solar cells for 2011 was US$1.2 billion.

Kinetic energy capture

Various forms of kinetic energy capture exist, e.g. hydroelectric schemes, wind energy (both large scale and micro-generation), and wave and tidal energy systems. Nanotechnology has a facilitating role in all of these systems including the use of advanced manufacturing and construction materials, surface coatings, corrosion prevention, control systems, sensors and measurement systems. Examples include hydrophobic and self-cleaning nanocoatings for wind turbine blades, high strength, lighter carbon nanotube-containing composites for wind turbine blades, high-performance paint protection systems, and high-performance and high-storage capacity fuel cells for the storage of captured energy.

Novel kinetic energy systems, employing nanomaterials, have also been recently developed such as energy capturing floor tiles that can be installed in areas where there is a high level of pedestrian activity.

There are a diverse range of materials, products and processes employed in this sector that can be supported by nanotechnologies and hence a mix of generic and more specific training needs.



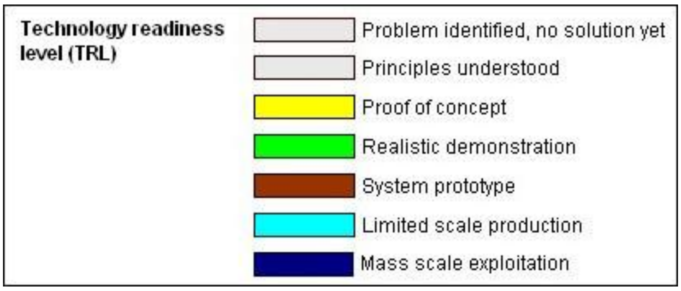
Fuel cells and energy storage

In both solar and kinetic energy capture, there is a need for energy storage as the energy generation process may be discontinuous. Electrical energy is difficult to store in large quantities. One potential solution is to convert into and store this energy as hydrogen, which can then be used as a fuel source for a *fuel cell*. For example, with wind energy, in particular windy periods the excess energy generated by a wind farm could be converted into hydrogen and stored for use in a number of applications, or to power fuel cells. The use of nanomaterials (e.g. nanoscale metal hydrides) allows for smaller and lighter fuel cells and more efficient hydrogen storage.

Nanomaterials can also improve fuel cell performance by increasing the conductivity of the electrolyte, the use of carbon nanotubes can produce battery electrodes that are ten times thinner and lighter and which have higher conductivity. In addition fuel cells require a catalyst such as platinum, which is very expensive. By using platinum nanoparticles or nanoparticles of other suitable catalytic materials costs can be lowered.

Much of the research into battery design has been focused onto the use of nanomaterials to produce smaller and lighter batteries for use in an increasingly wide range of consumer and professional products. However, the use of nanomaterials can also improve the performance and storage capacity of traditional types of battery where size is less of a concern and the ability to store large quantities of energy is more important.

Fuel cell and advanced battery technologies are likely to become more important with an increased focus on green energy production and apprentices will be likely to encounter such technologies in a number of settings across construction, facilities management and utilities, in terms of manufacture, installation and maintenance.

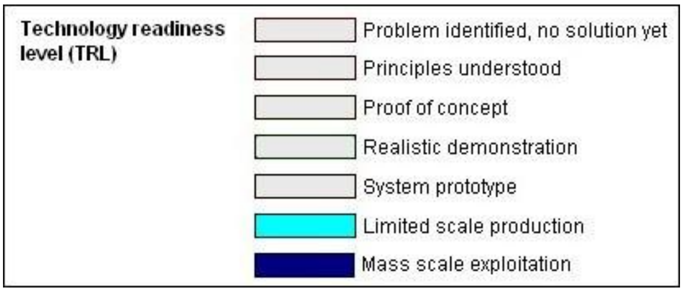


Economic impacts

The use of nanotechnology in energy storage was estimated to be a US$3.7 billion market by 2011 according to Lux Research (2007).

High-efficiency OLED-based lighting and displays

Organic light-emitting diodes (OLEDs) provide high-contrast and low-energy displays that are rapidly becoming the dominant technology for advanced electronic screens. They are already used in some cell phone and other smaller-scale applications. Current state-of-the-art OLEDs are produced using heavy-metal doped glass in order to achieve high efficiency and brightness, which makes them expensive to manufacture, heavy, rigid and fragile. Using a layer of tantalum oxide of thickness around 70nm it is now possible to produce OLEDs on flexible plastic which opens up a whole new range of potential energy-efficient, flexible and impact-resistant lighting and display applications. Because of the potentially ubiquitous application of such systems it is likely higher-level apprentices will encounter them in manufacturing, installation and maintenance situations.



Economic impacts

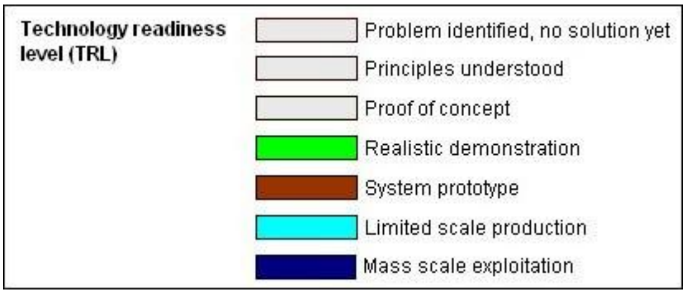
While there is limited OLED production at present, major manufacturers are gearing up for production and a global market of around US$8 billion is estimated by 2020

Flexible and printed electronics

Various low-cost printing methods can be used to create electrical circuits and devices on various substrates. Electrically conductive inks are deposited on the substrate, creating active or passive devices, such as thin film transistors or resistors. Printed electronics are expected to facilitate widespread, low-cost electronics for a wide range of applications such as flexible displays and smart labels. In a similar way to OLEDs, the application of nanotechnologies is underpinning the development of printed and flexible electronics.

Conductive inks may be inorganic, containing dispersions of inorganic nanoparticles such as silver, gold or copper, or novel organic conjugated polymers with conducting, semiconducting, electroluminescent, photovoltaic and other properties.

Again, due to the potentially widespread application of printed electronics, higher-level apprentices are likely to be involved in their manufacture, installation and use.



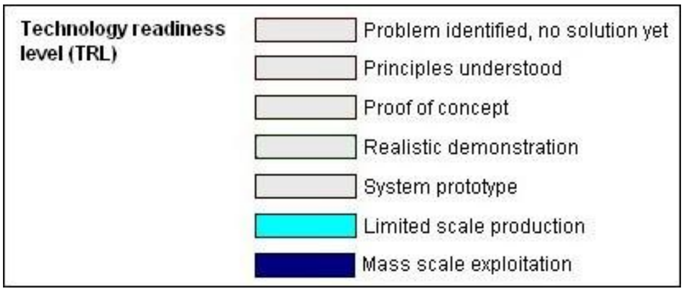
Economic impacts

IDTechEx predicts that the plastic electronics market will be worth around US$300bn by 2030. Applications are likely to include flexible displays (sometimes referred to as e-paper), electronic RFID tags, intelligent packaging, bio-sensors, disposable electronics and intelligent textiles.

Site remediation

In the construction and utilities sectors, the remediation of groundwater contamination and other site remediation activities have become increasingly important in the UK due to the limited availability of sites and the need to comply with legislation. In Europe as a whole, over 20000 sites require groundwater remediation. The traditional approach to remediation has been to use granular iron as a permeable reactive barrier but, with the application of nanotechnology, it is now possible to inject nano zero valent iron (nZVI) into the ground. nZVI has a massively increased surface area, reaction rates that are 25-30 times faster than previous methods, and a much greater absorption capacity. Other benefits include reduction of treatment time and cost, reduction of exposure for workers and the environment, reduced equipment costs due to the in-situ nature of the treatment, and effective treatment of a wide range of contaminants.

Apprentices in these sectors are likely to encounter these new types of nanomaterial-based remediation treatment and there are potential training needs in both how these treatments work, methods and in health and safety aspects.



Economic impacts

The net value of nano zero valent iron (nZVI) technologies to the UK economy has been estimated at around £2.4 billion over 20 years in a 2010 report for DEFRA.

Dust reduction products

A variety of solutions are available for dust reduction, which is of importance in construction, facilities management and utilities activities. A solution, based on nanotechnology, works by using an ecologically-safe, biodegradable, liquid copolymer to stabilize and solidify soils or aggregates to help prevent erosion and suppress dust. Once applied to the soil or aggregate, the long nanoparticulate copolymer molecules coalesce forming bonds between the soil or aggregate particles and cross-linking. As the water dissipates from the soil or aggregate, a durable and water resistant matrix of flexible solid-mass is created. Once cured, the product becomes completely transparent, leaving the natural landscape appearing untouched.

Apprentices may be involved in the application of such systems and a knowledge of how they work, and health and safety issues is therefore appropriate.

Pollution control, e.g. O_3, CO, NO_x, SO_2, VOCs, particulate matter (PM)

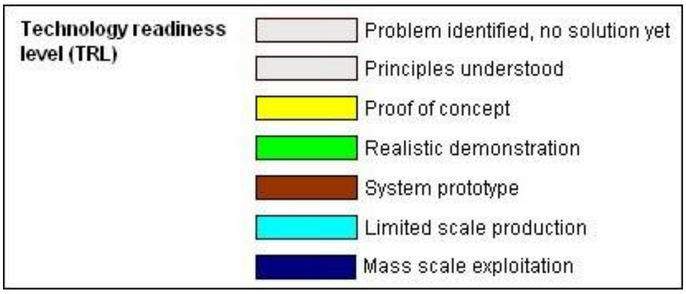
Despite a substantial decrease in many air pollutants since 1990 a significant proportion of the EU population live in cities where EU air quality limits, for the protection of human health, are exceeded. Air pollutants include:

- ozone (O3)
- particulate matter (PM1, PM2.5, PM10)
- carbon monoxide (CO)
- nitrogen oxides (NOx)
- sulphur dioxide (SO2)
- volatile organic compounds (VOC)

High levels of air pollutants can seriously impact those with existing respiratory or cardiac diseases so is a major public health issue. Coatings such as nanoscale titanium dioxide can help to break down these molecules through photocatalysis. Once recent development has been to coat concrete paving slabs in titanium oxide nanoparticles to help break down nitrogen oxides by catalysis in urban environments polluted by traffic. Reductions of 20% in NO_2 and up to 38% reduction in NO in modest sunshine have been reported for these products. Carbon capture from the burning of fossil fuels can be reduced by the use of nanomembrane filters in scrubbing systems and these are reported to use much less energy than conventional capture systems.

Nanofiltration systems is also being increasingly used to remove a range of pollutants from drinking water. In a trial at a water plant in France they have proved very successful in terms of eliminating organic matter and pesticides and reducing chlorine taste (important to customers). The operating costs, in comparison to traditional methods, were lower than expected.

Those apprentices working in the facilities management utilities sectors are likely to encounter an increasing variety of nanomaterial- or nanotechnology-based pollution control systems and knowledge of how they work and their installation and maintenance is therefore desirable.



Economic impacts

The market for nano-enabled water and wastewater applications is predicted to reach US$6.6 billion by 2015, up from US$1.6 billion in 2007 (OECD, 2012).

Biosensors

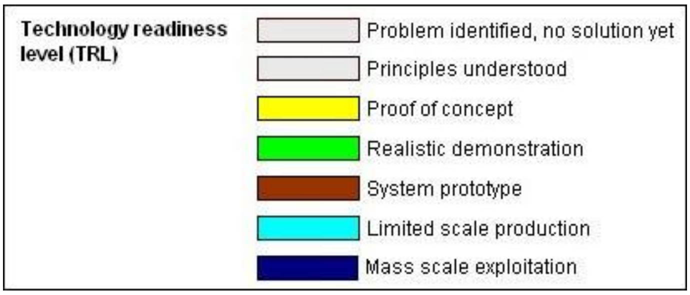
Biosensors increasingly employ sensing surfaces based on nanotechnologies. A typical sensor comprises a sensing surface which may be based on a biological material, derivative or biomolecule, or an artificial biomimetic surface; a transducing system (electrochemical, optical, piezoelectric or other mode of operation) that converts the reaction between the analyte and the biosensor surface to a signal; and a means of processing the signal.

Biosensors may be networked and distributed widely in the environment, may be used for a huge range of measurements or detection of a huge range of analytes, including pollutants, gases, indicators of air or water quality, in "smart homes" and in security applications (see below). (Bio)sensors may be incorporated into other systems. One recent example is the use of aligned, conductive carbon nanotubes in a highly-durable surface coating based on fly ash which can be used in highly-demanding applications such as bridge-building and offshore construction as an indicator of early structural failure. This nano-based system is expected to cost 1% of other existing solutions.

Because of their ability to be used in a wide range of networked applications across many activities in construction, facilities management and energy and utilities operations, it is very likely that higher level apprentices will be involved in the manufacture, installation, operation and maintenance of biosensor networks. Knowledge of their principles of operation will therefore be useful.

Biosensors in safety and security applications

Biosensors also increasingly feature as part of security and safety systems, e.g. for the detection of workplace contaminants, noxious compounds and in screening systems, e.g. for the detection of drugs of abuse, and as such, may be frequently encountered in construction and facilities management settings.



Economic impacts

A Frost and Sullivan market analysis suggests that the global revenue for the biosensors market will continue to exhibit strong growth and will exceed the €10 billion mark in the next seven years. Annual revenue growth rates are likely to be in the region of 12% to 14% by 2016.

Table 1: Summary of nanotechnology-enabled products and possible training needs		
Sector	**Type of nanotechnology-enabled product**	**Possible training needs**
Construction	Nano- concrete and cement Nanocomposites and reinforced polymers Self-cleaning glass Self-cleaning surface treatments Nano-structured surfaces, e.g. for water repellance Insulation materials, e.g. aerogels and nanofoams Paints and other applied protective coatings, e.g. wood treatments and anti-corrosion products Fire protection products Sealants and adhesives Functionalised textiles Solar energy capture Kinetic energy capture Fuel cells Energy storage High-efficiency OLED-based lighting and displays Flexible and printed electronics Site remediation products Dust reduction products Pollution control, e.g. e.g. O_3, CO, NO_x, SO_2, VOCs, particulate matter (PM) Sensors Monitoring of structural integrity Security applications	General note: There is a degree of overlap between the products and skills required in this sector and those in the facilities and energy/utilities sectors. Therefore, there will probably be a core of training needs that are common to all three sectors, as well as products, and processes, and their related training needs, that could be more sector-specific. Common training needs - what is nanotechnology? - why nanotechnology improves the performance of these products - benefits over traditional products - working with nanomaterials - what do I need to know? - nanomaterials - fixed in products or free? - how nanomaterials can get into the body and potential exposure routes - what are the risks, if any, in manufacture, use and disposal at end of life? - any preparatory treatments? - special precautions to be taken with each type of products - what to do in case of exposure to materials or accidents - reporting on incidents or problems - applicable legislation and standards - the precautionary principle – implications? Product- or site-specific training needs - how to use the product effectively and safely - product safety sheets - specific product risks - specific precautions and safety measures Dividing above into class and on-site training units

Facilities Management	Cleaning agents Anti-bacterial coatings and surface treatments Paints Anti-graffiti treatments Sealants and adhesives Applied protective coatings, e.g. for concrete Solar energy capture- maintenance Kinetic energy capture - maintenance Batteries - maintenance Fuel cells - maintenance Sensors – maintenance Vehicles – nano-based care products Vehicles – nano-based fuel supplements Ongoing monitoring of structural integrity Pollution control Dust reduction Security applications	General note: Probably a fairly high degree of overlap between this sector and the construction sector (see also notes for that sector), particularly in the case of materials that need to be reapplied on a regular basis, installations or systems that require regular maintenance, or retrofitting. Common training needs - what is nanotechnology? - why nanotechnology improves the performance of these products - benefits over traditional products - working with nanomaterials – what do I need to know? - nanomaterials - fixed in products or free? - how nanomaterials can get into the body and potential exposure routes - what are the risks, if any, in manufacture, use and disposal at end of life? - any preparatory treatments? - special precautions to be taken with each type of products - particular issues associated with maintenance - what to do in case of exposure to materials or accidents - reporting on incidents or problems - applicable legislation and standards - the precautionary principle – implications? Product- or site-specific training needs - how to use the product effectively and safely - product safety sheets - specific product risks - specific precautions and safety measures

Energy and Utilities	Solar energy capture Kinetic energy capture, e.g. nanomaterials used in wind turbine blades, etc. Nanomaterials and components in electricity-generating machinery, e.g. bearings, rotors, turbine blades, transformers High-temperature superconductors High-storage fuel cells and hydrogen storage Large-scale building-integrated energy capture and storage Carbon capture and storage Widely-distributed and networked sensors as part of an integrated energy management system Air pollution control, e.g. O_3, CO, NO_x, SO_2, VOCs, particulate matter (PM_x) Drinking water treatment and purification, including photocatalysis Waste water treatment, including removal of heavy metals (e.g. lead, cadmium, arsenic, mercury), hormones, organic matter, nitrates Desalination Groundwater remediation (e.g. using nano-zero valent iron) Use of nanomaterials in gas fracking Use of nanomaterials in the oil industry	General note: Reference should be made in this section to strong political and economic pressures towards green energy and lowering carbon footprint and the role of nanotechnology. Probably also a degree of overlap between this sector and the construction sector (see also notes for those sectors). Common training needs - what is nanotechnology? - why nanotechnology improves the performance of these products - benefits over traditional products - working with nanomaterials – what do I need to know? - Nanomaterials - fixed in products or free? - how nanomaterials can get into the body and potential exposure routes? - what are the risks, if any, in manufacture, use and disposal at end of life? - any preparatory treatments? - special precautions to be taken with each type of products - particular issues associated with maintenance - what to do in case of exposure to materials or accidents - reporting on incidents or problems - applicable legislation and standards - the precautionary principle – implications? Product- or site-specific training needs These could vary widely due to the diverse range of activities in this sector.

Apprenticeships - Views from employers and employees

While the following examples are drawn from industry sectors other than those primarily addressed in this feasibility study, they are included to illustrate the value that both employers and apprentices place on the inclusion of emerging technology training in higher-level apprenticeship programmes. It is worth noting also that a core module on nanotechnology may be equally applicable to these sectors.

University of Birmingham

"This is the first year in 10 years that we've been able to take on new apprentices at the University. Already, our two new apprentice technicians are proving invaluable members of the University and of our UBRacing (Formula Student) team," enthuses Carl Hingley, Senior Technician at the University of Birmingham School of Mechanical Engineering and Team Manager of UBRacing.

He continues: *"To me, engineering apprenticeships are critical to the future of UK industry. Not everyone can afford to go to University these days and so it's important that those not so well off have opportunities to develop a career and to get a taste of what it's like to work in real life engineering environments. The new apprentices are working with us on a Modern Apprenticeship Programme for three years, after which they will possess the practical skills and knowledge with which to confidently approach the jobs market."*

The students get to use a wide variety of equipment and machines in the workshop. Typical activities include welding, fabrication of tubes, laser cutting, CNC milling and lathe work, rapid prototyping, engine dynamometer testing, and so on. The students and apprentices also utilise a variety of software applications to support their design, build and test activities. Catia v5 software is used for all Computational Fluid Dynamics (CFD) work, Solidworks for 3D CAD modeling, RicardoWave for aerodynamics, and Matlab for simulation work.

Apprentice technician Becky in the UBRacing workshop said: *"The students and apprentices are working very well together. Typically, the apprentices will come to the workshop twice a week to work with the undergraduate students. Whilst here, the apprentices may be involved in manufacturing some of the components that the students have designed."*

http://www.heated.ac.uk/news.php?act=news&news_id=36&pageno=2

Nissan Sunderland

Nissan's Sunderland plant announces 25 new apprenticeships on its Trainee Maintenance Technician Scheme. The 25 new trainees will become part of the maintenance team who maintain the production facilities at Nissan Sunderland Plant, the UK's biggest carmaker. The structured programme leads to a foundation degree, and those accepted will also learn the Nissan Production Way, the foundation of the company's manufacturing excellence.

Nissan Sunderland plant engineering director, Richard Ebrahim, who started his own career as an apprentice, said: *"We are proud to support apprenticeships and would like to see more companies in our region doing so. Hiring apprentice supports the development of future managers and directors, giving our staff the practical skills and academic qualifications they will need for a successful career. We are looking for ambitious, intelligent people with a desire to learn and work hard. In return they are guaranteed a challenging and rewarding career at a company that is at the forefront of the UK manufacturing industry."*

One of the plant's current apprentices is Ethan Marshall, who has just been named Nissan Sunderland Plant's Trainee Maintenance Technician of the Year. He started the five-year scheme in January 2008 and is assigned to Trim and Chassis No. 1 Shop at the plant, where the Qashqai and Qashqai+2 are manufactured. Ethan, 21, from Chester-le-Street, is currently completing the final year of the Foundation Degree in Maintenance Engineering. His job involves activities such as facility improvements, software improvements, reducing breakdowns on equipment and AGV production cover. He said:

"I chose an apprenticeship because it would enable me to gain valuable qualifications in engineering, both practical and theoretical, while being paid. It also allows me to apply skills to real life situations and, at the end, have a secure career with good prospects."

The five-year Trainee Maintenance Technician scheme combines theoretical and practical skills, giving successful applicants the chance to work towards nationally-recognised qualifications through on-the-job and academic training, while earning a competitive salary.

Chemical Industries Association (UK)

"Rediscovering the Apprenticeship" (7 February 2011)

Technical industries like chemicals and pharmaceuticals require a broad range of skills and a highly trained workforce. To find the technical skills they need companies are increasingly looking at the value apprenticeships offer.

Through apprenticeships, companies are training a new generation of employees to the specific standards they require and can be confident that their employee has been thoroughly trained for the job they are being asked to do. Anecdotal evidence suggests that the apprenticeship route also leads to greater staff loyalty.

The benefits to the apprentice are many, especially in an industry such as chemicals that offers high quality training, good career prospects and salaries around 40% more than other manufacturing sectors. With the increase in tuition fees, an option to finish your training debt free and with several years' industry experience under your belt it is an attractive prospect.

At a recent meeting of the Chemical Industry All Party Parliamentary Group, apprentices Sarah Porter and Richard Davies called on MPs to campaign for a shakeup in careers advice. They argued for the need to ensure that apprenticeships are better understood and promoted to school leavers and sixth formers. By giving MPs an insight into what a modern apprenticeship is like, they convinced MPs that more needed to be done to transform the image of apprenticeships.

In January, Esther McVey MP who chairs the Chemical Industry All Party Parliamentary Group led a debate in the House of Commons on careers advice, she argued for better careers advice on apprenticeships and said *"We need to increase understanding of the status of apprenticeships."*

Responding on behalf of the Government, the Minister for Further Education, Skills and Lifelong Learning, Mr John Hayes said:

"… one would have expected teachers to know rather more about apprenticeships than they do. As they do not have that information at their disposal, they cannot always match people's aspirations and talents to the opportunities that I spoke of earlier. That is why we need independent, high quality, up to date and impartial advice and guidance for all young people."

Case Studies

Case Study 1: Sarah Porter, Apprentice in Research and Development (Innovia Films, Cumbria)

Sarah Porter is an Apprentice in Research and Development at Innovia Films in Cumbria. Sarah had started to follow the route laid out for her by her Sixth Form College and applied for a traditional chemistry degree. However she had doubts that this would satisfy her and started to investigate other opportunities. Innovia Films had made the effort to go into Sarah's school with a CREST project for sixth formers so she had become aware of alternatives available within the chemical industry.

Describing what motivated her to choose the apprenticeship route, Sarah said

"I felt that the system was trying to force me down a path I didn't want to take. I was very motivated about my interest in science, my education and a career but not university. An apprenticeship was not something that had been mentioned in careers advice but it seemed the ideal way to combine continued education, at the same time as getting on with my life.

I work at Innovia Films four days a week and study at Northumbria University in Newcastle one day a week. I do have to fit in course work at evenings and weekends but so do most students and my company is supportive. After six months at Innovia Films, I was already applying my knowledge from college to conduct my own testing experiments and within a year I was writing my own reports.

Friends who took the university route are envious that I have a good job and no student debt - I am part of the way towards a degree and with several years' work experience already on my CV. I have already my career whilst university graduates are struggling to find employment or even unpaid internships. Outside of work my passion is horses, which is not a cheap hobby to have. If I was a student there is no way I could have afforded to keep going and my skiing holiday in March would have been off the cards too.

I think the image of apprenticeships needs a makeover. It is not a second rate option, but a viable alternative for technically minded, intelligent individuals who prefer to learn on the job rather than just from the text books."

<u>Case Study 2:</u> Richard Davies, Apprentice in Mechanical Inspection (Shell, Merseyside)

Richard Davies is currently an apprentice in mechanical inspection at Shell in Merseyside.

Richard started sixth form and completed his first year of AS studies but had not found the experience motivating and was looking for an alternative to another year at school. Richard said *"I knew I did not want to go to university, the potential costs were daunting and I wanted to move on from desk based learning to something more practical that was likely to lead to a good job".*

The TTE Training LTD Ellesmere Port who provide technical education courses had been into Richard's school so he was aware of some of the benefits of an apprenticeship and at an open day it was easy to get in touch with them to work out which course suited him.

The apprenticeship that Richard secured is sponsored by Shell UK, it began with a two year broad based technical BTEC that ranged across many engineering disciplines.

It was then up to Richard to choose a specialisation when he began working at the Shell site for 18months to complete the NVQ level 3 qualification along with a HNC, Richard still attends college in Liverpool one day a week and sometimes has to fit in follow up work at home.

Commenting on the BTEC course Richard said *"the course at TTE gave me a good insight into the different options open to me before I specialised, the broad base means I understand many of the challenges that colleagues in other engineering roles at Shell will be facing. The rotations at Shell mean I get to experience working on different parts of the Stanlow site."*

On starting his placement at Shell Richard said *"the apprenticeship route means I think I am better placed to make a proper contribution in my job much more quickly than a graduate could, because of the practical knowledge I have gained during the apprenticeship. The great thing about Shell at the Stanlow site is that they have been training apprentices for 20 years so you can see the career paths they have taken and the advantages of being an apprentice compared to a graduate".*

Commenting on the apprenticeship route, Richard said*, "I was the first in my year at school to go to TTE, but a few others have followed and there were more the year after, one friend couldn't get in and went to University instead. My friends at university are definitely envious that I have no student debt, and that Shell has confirmed my job on completion of my apprenticeship. I think apprenticeships need to be more heavily promoted as an alternative option to university rather than a second choice for those who don't feel suited to a purely academic route".*

Survey

The survey examines the current state of knowledge of potential employers in these sectors concerning nanotechnologies and nanotechnology-enabled products, explores their needs concerning the skill sets of higher-level apprentices and the career opportunities that may be available to suitably-qualified apprentices.

- Appendix 1 shows a copy of the survey questionnaire form
- Appendix 2 shows the results of the survey carried out with delivery partners

- The survey with delivery partners indicated the following;
- Lack of awareness and understanding of Nano-Science and Nanotechnologies
- Lack of awareness of commercially available Nanotechnologies
- Delivery partners had an interest in learning about Nanotechnology
- Delivery partners had an interest in delivering Nanotechnology training to learners
- Delivery partners thought it would be desirable to develop a units in Nanotechnology for the Apprenticeship Framework
- Didn't know if businesses would attracted by apprentices trained in Nanotechnology

The results indicate that there is an interest in Nanotechnology and the benefits provided by the technologies, however there is a lack of knowledge among training providers of this technology and due to the lack of knowledge training providers have no idea if employers would find the training attractive or of benefit for their apprentices & staff. This also indicates a lack of knowledge within the business sector on what Nanotechnologies are available and the benefits that they provide.

This mini survey has indicated a need for educating the business communities as well as training providers.

Recommendations

This feasibility study has been of great value and provided the project working group with valuable information on the current status amongst businesses, training providers and individuals in relation to Nano-Science and Nanotechnologies.

On the basis of the emergence of nanotechnology-based products and processes in the construction, facilities management and energy/utilities sectors and sector-based skills required to maximize the potential impacts of nanotechnology in these sectors there is a need to develop a series of Nanotechnology, units od assessments for the Apprenticeship Framework.

For UK businesses to remain competitive in the National and International market place and ensure that the UK has established curriculum to train professionals and students alike in new emerging nano-based technologies it is essential to close the skills gaps that exist in both the business and education sectors.

The lack of knowledge and skills within the UK has identified a clear need for both informal and formal training for learners and teachers alike

On the basis of the research carried out for this project, discussion among key stakeholders within the project working group and the survey carried out with training providers, the project working group make the following recommendations;

1. Due to lack of knowledge and continual emergence of new and enhanced Nano-based technologies it is not feasible to develop a completely new Apprenticeship Framework in Nanotechnology. It is too early in the technology lifecycle to create a new and specific Nanotechnology Framework.
2. To develop a generic and optional foundation knowledge-based level 3 Nanotechnology unit for the Apprenticeship Framework that can be used in all three identified industry sectors

Recommendations for Further Developments

Develop a series of Nanotechnology units that are;

- Generic units for a spectrum of industries
- Specific to Industry sectors
- Specific units for specialist job roles

Develop learning content;

- Generic content for a spectrum of industries
- Learning content for specific industry sectors
- Specialist learning content for specific job roles

Develop formal and informal training courses for;

- Teachers and other training providers
- Businesses
- Individual Learners

Nanotechnology training for teachers as part of their Continual Professional Development (CPD) training

Appendix 1 – Survey Questionnaire

LSIS Skills & Employer Responsiveness Nanotechnology Feasibility Project

Questionnaire

1 Is your company or organisation:

		Yes	No	Don't Know
1a	A manufacturer of nanomaterials or nano-enabled products?	☐	☐	☐
1b	Aware of the nanoproducts available in its sector?	☐	☐	☐
1c	Aware of the benefits that nano-enabled products may bring in its sector?	☐	☐	☐
1d	Currently using nanomaterials or nanotechnology-enabled products in its activities?	☐	☐	☐

2 Does your company or organisation:

		Yes	No	Don't Know
2a	Have an apprentice training scheme?	☐	☐	☐
2b	If so, require that apprentices work with novel materials like nanoproducts?	☐	☐	☐
2c	If so, have any apprentice training in place covering novel materials like nanoproducts?	☐	☐	☐
2d	Have an interest in the development of a core apprenticeship module covering nanotechnologies?	☐	☐	☐

3 Do you think that the development of a core apprentice training module on nanotechnologies would be desirable?

Yes	No	Don't Know
☐	☐	☐

4 If so, should it cover:

4a	An introduction to what the nanoscale, nanomaterials and nanotechnology are?	☐	☐	☐
4b	How novel properties at the nanoscale affect material characteristics and product functionality?	☐	☐	☐
4c	An overview of the different ways nanotechnology can be used?	☐	☐	☐
4d	The possible risks, as well as the benefits, associated with nanotechnology?	☐	☐	☐
4e	Information on applicable regulations and legislation applying to such materials and products?	☐	☐	☐
4f	How to identify and manage risks, obtain safety information, and handle materials safely?	☐	☐	☐
4h	Precautions in preparation, using, installing, maintaining and disposing of nanoproducts?	☐	☐	☐
4h	Pointers to more specific technical information for nanoproducts used in different sectors?	☐	☐	☐

5 Would such training make apprentices more attractive to your company?

Yes	No	Don't Know
☐	☐	☐

6 Are there additional comments that you would like to make:

6a About the impact of nanotechnology in your sector?

6b About the need for apprentice training in novel technologies, like nanotechnology, to remain innovative and competitive?

6c About the specific content of any nanotechnology core module(s) for apprentices?

6d Any other comments?

7 Your details

Company/organisation:

Name

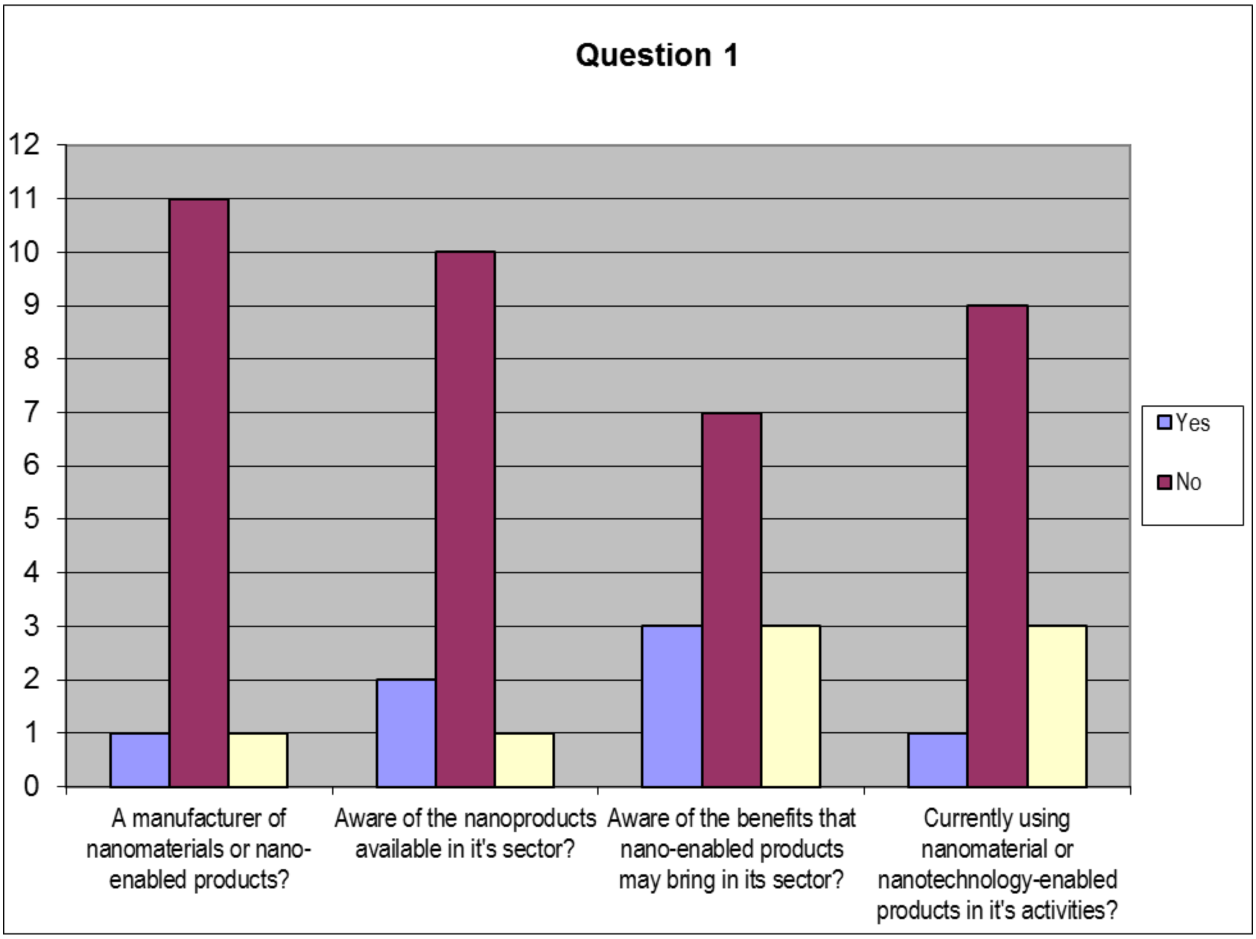
Position

Contact details

Appendix 2 – Results of Questionnaire

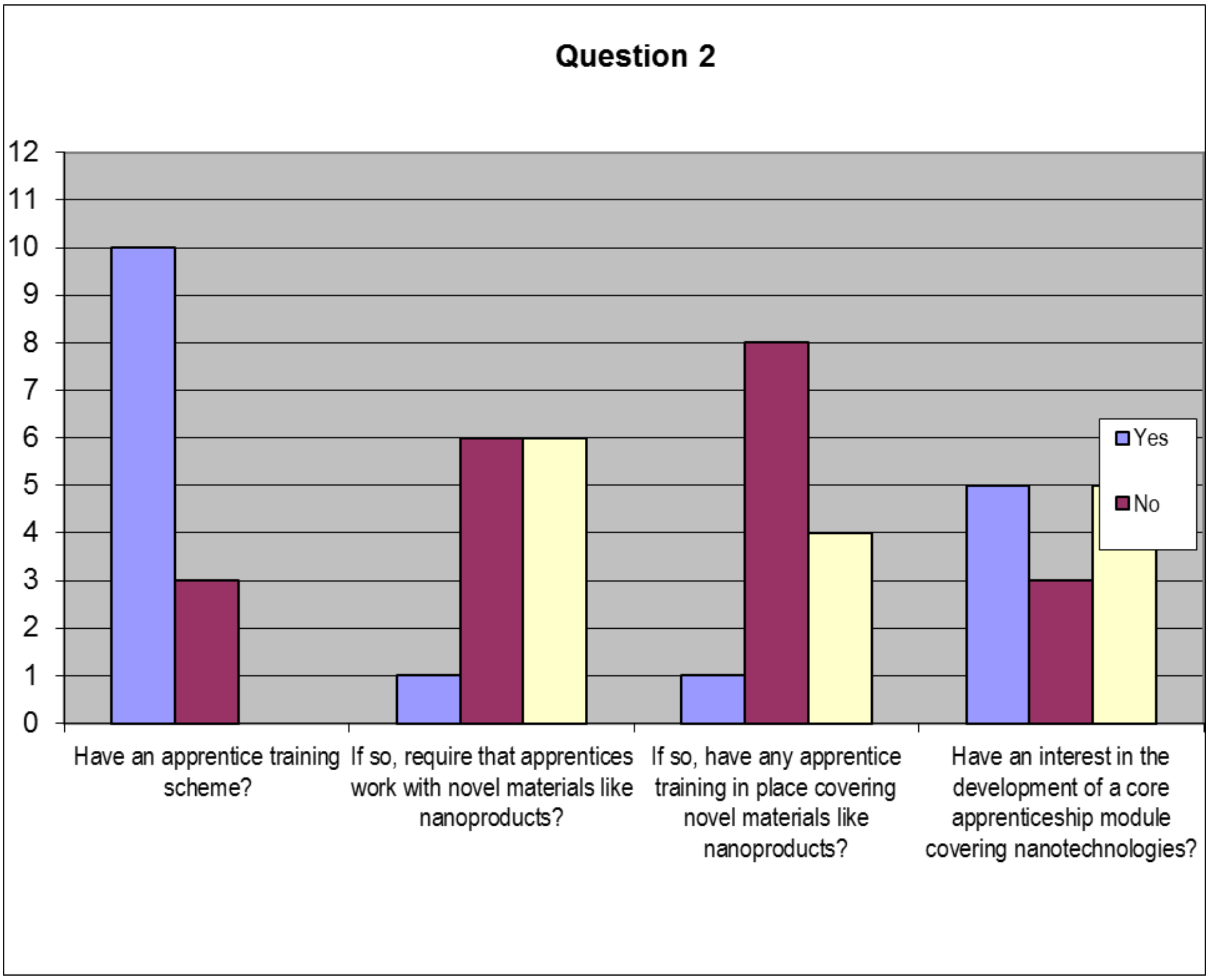
Question 1

1	**Is your company or organisation:**	Yes	No	Don't Know
1a	A manufacturer of nanomaterials or nano-enabled products?	1	11	1
1b	Aware of the nanoproducts available in it's sector?	2	10	1
1c	Aware of the benefits that nano-enabled products may bring in its sector?	3	7	3
1d	Currently using nanomaterial or nanotechnology-enabled products in it's activities?	1	9	3



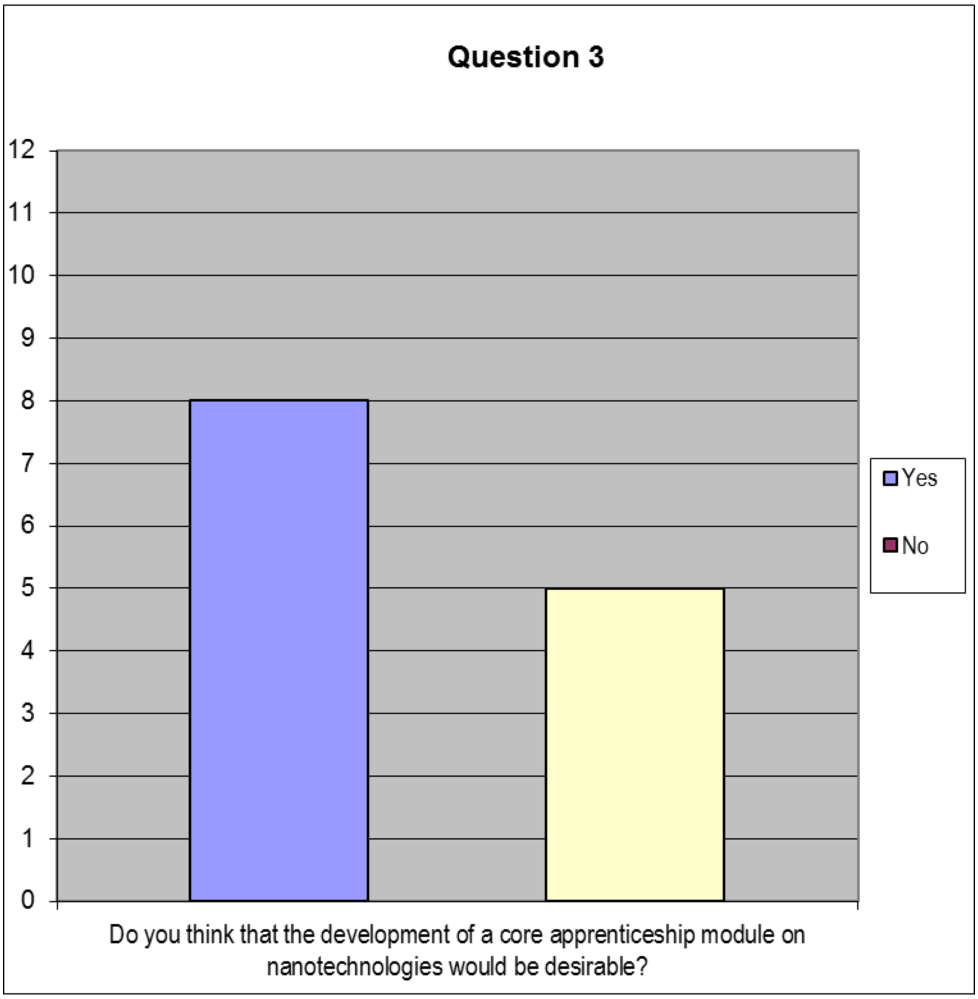
Question 2

2	Does your company or organisation:	Yes	No	Don't Know
2a	Have an apprentice training scheme?	10	3	0
2b	If so, require that apprentices work with novel materials like nanoproducts?	1	6	6
2c	If so, have any apprentice training in place covering novel materials like nanoproducts?	1	8	4
2d	Have an interest in the development of a core apprenticeship module covering nanotechnologies?	5	3	5



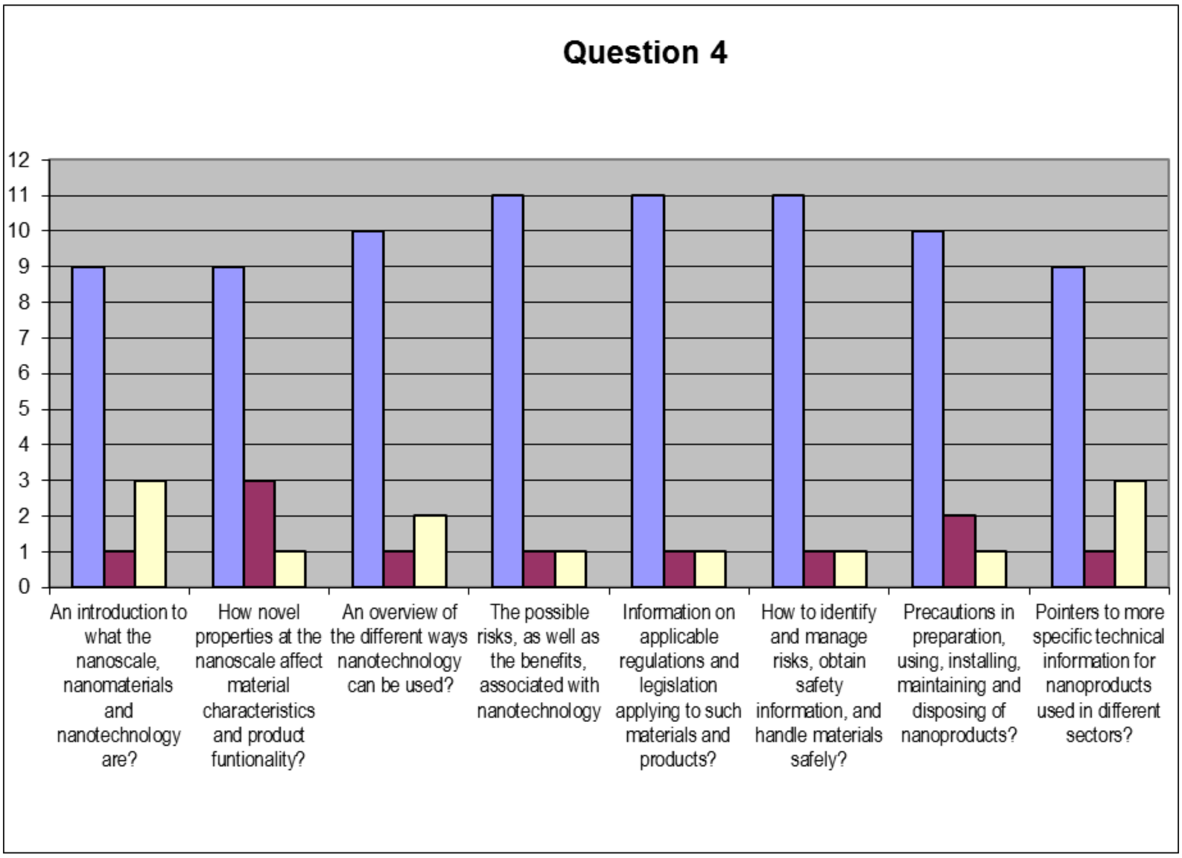
Question 3

		Yes	No	Don't Know
3	**Do you think that the development of a core apprenticeship module on nanotechnologies would be desirable?**	8	0	5



Question 4

4	**If so, should it cover:**	Yes	No	Don't Know
4a	An introduction to what the nanoscale, nanomaterials and nanotechnology are?	9	1	3
4b	How novel properties at the nanoscale affect material characteristics and product functionality?	9	3	1
4c	An overview of the different ways nanotechnology can be used?	10	1	2
4d	The possible risks, as well as the benefits, associated with nanotechnology	11	1	1
4e	Information on applicable regulations and legislation applying to such materials and products?	11	1	1
4f	How to identify and manage risks, obtain safety information, and handle materials safely?	11	1	1
4g	Precautions in preparation, using, installing, maintaining and disposing of nanoproducts?	10	2	1
4h	Pointers to more specific technical information for nanoproducts used in different sectors?	9	1	3



Question 5

	Yes	No	Don't Know
5 **Would such training make apprentices more attractive to your company?**	2	4	7