Practical skills of new undergraduates

Report on research workshops delivered on behalf of the Gatsby Charitable Foundation

5 October 2011

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Summary of key findings

Introduction

The Gatsby Charitable Foundation commissioned four research workshops to explore undergraduate teachers' views on how well new science undergraduates are equipped with practical skills. It is intended to use the results of the workshops to inform the development of science A levels. The workshops form part of a wider review being undertaken by Gatsby which aims to explore whether practical work in school science is fit-for-purpose.
The four workshops were held in September 2011 in Manchester, Bristol and London. Forty-five HE staff from bioscience, chemistry and physics departments in twenty-five UK universities participated.

During the workshops, participants were encouraged to define 'practical work' as broadly as they felt was appropriate. Commonly it was used to include activities undertaken in the lab, but for some subjects (biosciences and applied chemistry) also in the field. 'Practical skills' were then framed as the skills required to undertake effective practical work.

Key findings: practical skills needed by new undergraduates to succeed

Workshop participants identified the following sets of core practical skills as important for first year undergraduates' success in all their disciplines:

- **Confidence and a positive attitude** in the lab or field, including students' engagement in their own learning;
- **Independent thinking**: the ability to solve problems independently in a practical context was desirable, but participants also wanted their students to follow instructions so there was some contradiction here;
- **Appreciation and application of scientific methods and practices**, including appropriate experimental planning, time management in the lab, observational skills, note-taking and scientific report-writing;
- **Numeracy** and mathematical skills, specifically the application of mathematical concepts in a practical context, data analysis and the ability to sense-check quantities etc.;
- **The ability to work safely**, including awareness and use of safe practices was raised by all groups but especially prioritised by chemists;
- **IT skills**, especially in MS Excel, but also Word and PowerPoint;
- **Research and referencing**, including online and offline research skills, referencing and avoidance of plagiarism;
- **Communication, social and presentation skills** including collaborative working, IT skills and verbal presentation skills.

In addition to these core practical skills, participants identified some practical skills that were unique to their individual scientific disciplines.

- **Chemistry lab techniques** including dexterity and manipulation, using glassware, burettes and titrations, accurate weighing and preparing solutions. The chemists also identified some **specific experiments** that would be beneficial for students to have conducted: synthesis of aspirin, melting point, recrystallization, and chromatography.

- **Physics instruments and equipment.** In Physics, the specific skills related to familiarity with instruments and equipment that would be used in the first year Physics lab. The following instruments were listed: oscilloscope, stopwatch, Vernier scale, DC I/V source, AC signal generator, frequency counter, multimeters (I, V, R, AC/DC), and simple circuits.
- **Biosciences lab techniques** included: calibration curves, assays, spectrophotometry, pH buffers, weighing, microscopy, density and pipettes. **Field skills** were also discussed.

There are some striking trends in the results from the workshops. Firstly, there was a surprising level of agreement across the three disciplines about the core skills that were important. Secondly, the core skills and attributes were rated as more important for students as they entered university than the skills specific to scientific disciplines. The exception is the use of Physics equipment. Chemists and bioscientists expected that students would develop the specific skills throughout university. Thirdly, the general skills were also the ones that were seen as either d0eclining or improving. Participants tended to feel that the skills they ranked as most important to success on entry to university (such as confidence, independent thinking, scientific method) were in decline, and those that were less important (IT, communication) were improving. These changes were widely stated as having taken place over the last 10-15 years, although two participants felt there had been a sharp decline affecting the undergraduates that had just finished first year. Finally, the extent to which students are seen as well-equipped with numeracy skills varied widely between the disciplines, possibly related to whether or not A Level Maths is an entry requirement.

University teachers said that their main source of evidence for the skill levels they reported was the students themselves. Many highlighted that they did not have a comprehensive understanding of what was taught at school, so they did not always feel confident making a judgement about whether or not students had been exposed to a particular skill or experiment. They expressed a desire to have a better understanding of how practical work is taught in schools and were interested in finding out about this at the workshops.

Key findings: how universities are responding

Most of the groups said that the practical skills of their entry level students are a concern. While most felt that the issue was one they could cope with through their undergraduate teaching, it was widely acknowledged that the potential depth of the university-level practical learning was compromised. Many participants said that they assume their new undergraduates will come in with limited or no practical skills.

Workshop participant described a variety of ways in which universities are taking action to enhance students' practical skills. These included:

- Focusing on skills development in first year practical courses;
- Changes to course structures including pre-labs and project work;
- Training for teachers and demonstrators;
- Assessment methods during practical classes;
- Outreach and links with schools.

Practical skills of new engineering undergraduates

No engineers responded to the invitation to participate in the research workshops, so four interviews were conducted with representatives from professional engineering bodies that have an overview of the community.

Interviewees agreed with workshop participants that practical skills of new undergraduates were an issue. However the issue was seen as perhaps third or fourth in a list of priorities after maths – which was described as the top priority – and skills which the engineers did not spontaneously associate with practical work such as problem solving or physics ability. In addition to these, specific skills were related to individual branches of engineering, so computing and electronics skills were relevant to electronic engineering, while sketching, making and hand-eye skills were seen as important in civil engineering. It was clear from the interviews that the understanding of what is meant by 'practical work' in engineering is different from that in the sciences, which may affect shared discourse on the issue as it relates to school education.

1 Introduction

The Gatsby Charitable Foundation was established in 1967 by David Sainsbury (now Lord Sainsbury of Turville). For more than two decades Gatsby has developed and managed a range of innovative projects to strengthen science, technology, engineering and mathematics (STEM) in UK schools and colleges.

Gatsby is currently engaged in a review of how well practical work in school science is fit-for-purpose. The review will run from August 2011 until August 2012. As part of this review, Gatsby is investigating how Science A Levels (or equivalents) can better prepare young people for undergraduate courses in the sciences in terms of practical skills.

In May 2011, Laura Grant Associates conducted a small scale study in this area to inform Gatsby's submission to the House of Commons Science & Technology Committee inquiry into the teaching of practical work in schools. The findings of that study revealed widely held perceptions about a deficit in the lab skills of new undergraduates, and a perceived decline in these skills among many. To further explore these concerns, a series of four workshops (each comprising two focus groups) was convened in September 2011. The workshops included a wider range of science-related subjects and different types of institution than those represented in the preliminary study.

2 Research objectives

The following objectives were identified to shape the research workshops:

1. Main objective: to provide a detailed list of practical skills that universities require on entry to undergraduate courses in key disciplines – this will be used to compare with GCE A Levels in the sciences and to inform the development of new specifications and criteria from 2012;
2. to probe some of the top level findings of the preliminary survey, particularly: differences between disciplines; low confidence vs genuine skill deficit; and to gain a sense of how widely-held some of the views expressed in that survey are.
3. to inform a potential wider survey of HEIs regarding practical skills;
4. to identify individuals who may be interested in continuing to work with Gatsby on the development of GCE A Levels;
5. to gather any other opinions and evidence regarding the deficit in practical skills among new undergraduates and its impacts, and possibly any 'good practice' implemented e.g. development of undergraduate curricula in partnership with a secondary school that has overcome these deficits.

3 Methodology

3.1 Research workshops

It was agreed that a qualitative approach to the research questions would be a useful starting point, as this would allow lists of skills to be developed in the absence of researchers' assumptions. These can then be quantified in subsequent stages of the review if appropriate.

The research was conducted via a series of four half-day workshops. Recruitment was conducted via a database of contacts from relevant departments in UK universities that was developed as a first stage, and the workshops were also marketed with the support of a range of organisations and professional bodies that are active in HE. Four workshops were delivered, and participants from two disciplines were invited to each. Workshops were held in Manchester, Bristol and London.

3.2 Outline workshop agenda

Participants were divided into two focus groups depending on the subject that they taught for the first part of the workshop, but the groups were mixed for the wider discussions at the end of the afternoon. An outline of the agenda for the workshops is given below and the full facilitators' guide can be found in Appendix IV.

12.30 **Registration and lunch**

13.00 **Introductions**

13.30 **First year activities**: in groups with others from similar subjects, participants discussed the experiments they require first years to undertake, and grouped similar experiments together. This provided information on which types of experiments were common across several departments, and which were unique to a few.

14.00 **Required practical skills**: Based on the outcomes of the discussions above, participants discuss the practical skills required for new undergraduates to succeed. At this stage participants were able to define the term 'practical skills' for themselves. Skills were ranked on a matrix that asked which were most important for success, and which students had been taught, had been taught but lacked confidence to use, and were well able to use. Participants were also prompted to mark which skills were improving and/or declining, and to explain their sources of evidence for the skills they identified.

15.00 **Coffee break**

15.15 **Wider discussions** in mixed groups to reflect on similarities and differences across disciplines. The implications of any patterns in the skills were also discussed, and the steps taken by universities to address this. Finally, participants were invited to suggest further questions that would be interesting for the wider review to explore.

16.15 **Final comments** and discussion of next steps with the reporting.

16.30 **Finish**

Ahead of the workshops, participants were asked to prepare a list of the activities they ask their first year undergraduates to undertake. They were also sent a list of the workshop research questions to consider. Several participants discussed these with colleagues (some gathered written feedback too) ahead of the workshops themselves.

Representatives from Gatsby attended the workshops to observe the discussions, and were able to ask questions during discussions when invited to do so by the facilitators. Participants were often keen to hear more about the way that A Level teaching is organised from the Gatsby representatives that attended.

3.3 Sample

Fifty-two participants registered for the workshops and 45 attended. Of those that were unable to attend, five gave apologies. Twenty-five universities were represented in the sample. A full list of participating institutions is provided in Appendix I.

The sample breaks down as follows:

Location and date	Subject areas (incl. associated applied subjects)	Bioscientists	Chemists	Physicists	Engineers	Total
Manchester 6 September	Chemistry & Physics	-	7	4	-	**11**
Bristol 7 September	Biosciences & Chemistry	5	5	-	-	**10**
London 8 September	Biosciences & Chemistry	4	11	-	-	**15**
London 13 September	Physics & Engineering	-	-	9	0	**9**
	Total	**9**	**23**	**13**	**0**	**45**

There was some discussion about the extent to which engineering and the medical professions should be included in the research. It was decided that medical professions would not be targeted, but that one of the workshops would be open to engineers. However, no engineers registered for the workshops. Feedback from some engineers that were invited suggested that the focus on science in the invitation might have meant engineers were less likely to see the relevance of the workshops to them. In order to explore the views of the engineering community, four interviews with representatives from engineering professional bodies were conducted and the findings from these are presented in Section 8.

Focus groups	
Biosciences	1 (n=5)
Mixed Biosciences and Chemistry	1 (n=8)
Chemistry	3 (n=7, n=5, n=7)
Physics	3 (n=4, n=4, n=5)

Workshop attendees were split into groups by discipline for the first part of the workshops. The numbers in the groups ranged from 4-8. As there is the largest proportion of chemists in the sample, the Chemistry groups tended to be larger than the Biosciences or Physics groups.

At one of the London workshops, there was a large imbalance between attendees from different disciplines. It was decided to convene a mixed group of Bioscientists and chemists. They were invited to record their ideas on different coloured post-it notes so it has been possible to separate the ideas from the disciplines for some of the analysis, although of course the group discussions involved both disciplines in this case. The smaller number of groups involving Bioscientists, the smaller number of Bioscientists that participated in the workshops and the diversity of the discipline means the results for that discipline are presented here with less confidence than for Physics or Chemistry.

During the workshops, participants were asked to capture ideas on post-it notes. In addition, facilitators took written notes covering the main points of the discussion. Quotes included in this report are taken from those notes, so represent near-verbatim comments.

3.4 Data analysis

Data against the different research questions were analysed differently.

For the lists of first year activities, the 'shared' and 'unique' activities were combined. Some groups had clustered similar experiments, so these clusters were used to organise similar experiments suggested by other groups. The result is the lists for each discipline provided in Section 4.

The skills for success were the main focus of the analysis. Participants had written these on post-it notes and ranked them on a matrix. They had also used green and red stickers to denote which skills they thought were improving and which were in decline. The post-it notes were grouped into themes to create an initial framework for analysis of the results. The notes from all of the group discussions were then coded into this framework using NVivo qualitative analysis software. The matrices created by each focus group are provided in full in Appendix III, and the outcomes of the analysis are presented in Section 5.

The discussions in the mixed groups towards the end of the workshops were wide-ranging and very interesting. However much of what was discussed related to HE teaching and was somewhat outside the scope of the original research. The notes from these discussions were reviewed by the research team, and the key issues identified. These are presented in Section 6.

4 First year activities

The first year activities that were shared between departments are presented below. It is important to note that not all students would complete all of the experiments listed. 'Shared' experiments were defined as those delivered by more than one institution in an individual focus group. It is not possible to identify how common the individual experiments are as the workshops did not record how many institutions deliver each one. Therefore, the most useful way to read the lists is to consider the common areas of practical work that were identified in the workshops, and use the lists of individual activities as examples of experiments that two or more university departments include.

Unique activities that were captured on the post-it noted during discussions are also included here, but these are by no means exhaustive lists.

4.1 Bioscience first year activities

A significant factor in the area of biological sciences is the diversity of courses taught at universities. It ranges from 'whole organism' biology, including ecology and zoology, through physiology and biochemistry to biomedical sciences and biotechnology. For the purposes of this research the discussions focused on field work and 'wet' laboratory activities and excluded computer work. There was variation in the way that Biosciences courses are organised in different institutions. Some have a common first year programme for students studying on different courses, e.g. for students studying Biology and Biomedical Sciences, while others have separate first years, but with some practical activities in common. In the institutions without a common first year, the shared practical activities are often aimed at teaching practical skills such as numeracy, molarity or experimental design. In almost all cases students are taught in pairs or small groups, very often this is determined by the availability of laboratory time and/or equipment.

Shared first year activities

Physiology

- Cardiovascular system measurement
- Measurement of respiratory systems
- E.g. heart rate, lung function, metabolic rate
- Blood pressure

Microbiology and cellular biology

- Microscopy
- Staining
- Histology
- Streaking

Techniques

- Report writing
- Lab safety

Field work

- Observations and identifications
- Sampling

Biochemistry activities and techniques

- pH and buffers
- Enzyme kinetics
- Measurement of metabolites (spectrophotometer)
- Enzyme assays
- Agarose gels
- Calibration curve construction and use
- Use of automatic pipettes (Gilson pipettes)
- Molarity and dilutions
- Statistics/data analysis
- Preparation of solutions
- Centrifugations of blood samples
- Paper chromatography

Participants also mentioned that topics such as ecology, ecosystems, chromosomes, mitosis and meiosis would have associated practical activities.

Unique first year activities

- Membrane permeability
- Mitochondrial respiration (O2 electrode)
- Radioactivity (and its use in biochemistry)
- ELISA (Enzyme-linked immunosorbent assay)
- Polymerase chain reaction
- Use of counting chamber (microscope)
- Column chromatography
- Measurements of BMI, body fat (skin callipers)

4.2 Chemistry first year activities

Generally there was widespread overlap of activities included in first year Chemistry practicals. There are some differences in how laboratory activities are organised in first year as some universities rotate students between organic, inorganic and physical Chemistry and others do not use those distinctions, linking experiments more closely to lecture courses. There was agreement that basic techniques need to be taught in semester 1 and most of the universities deliver some kind of preparatory or pre-lab training. Most participants reported that their lab manuals and scripts were quite prescriptive in the first year, moving towards a more Problem Based Learning (PBL) approach as the students progress. For the groups of Chemists that discussed this in greatest depth, a minority of universities included some elements of PBL in the first year, but most said they introduce it in the second year.

Shared first year activities

Kinetics
- Iodination of propanone
- Hydrolysis of ethyl formate
- Persulphate – Iodide clock, reactions initial rates method
- Diazonum slat decomposition

ThermoChemistry/thermodynamics
- Enthalpy of combustion
- Equlibrium between NO2 and N2O4 (dinitrogen tetroxide)
- Phase equilibria- properties of partially miscible liquids
- Determination of molar mass and enthalpy of fusion from depression freezing point
- Flow calorimetry
- Ice calorimetry – heat formation of Magnesium ion
- Enthalpy of vaporisation of methanol
- Dissociation constant of ethanoic acid by conductance

Extraction and separation methods
- Recrystallisation and qualitative tests
- Comparison of extraction methods in the analysis of aspirin
- Purification of trans stilbene
- Separation and extraction
- Determination of appropriate recrystallisation solvent
- Thin layer chromatography

Analytical
- Analysis of water hardness by complexometric titration
- Acid/base equilibria
- Alkalinity of natural waters
- Standardisation of HCl and NaOH using borax
- Gravimetric analysis
- Determination of relative molecular mass by precipitation
- Determination of Calcium and Magnesium by flame atomic absorption spectrum

Spectroscopy
- IR spectroscopy
- Spectroscopy of copper glycinate
- Spectrophotometric determination of copper (UV-Vis)
- Selective reduction reactions and 'unknowns' from spectroscopic and physical properties

Qualitative analysis
- Reactions of Group 1 elements
- Reactions of Group 17 elements
- Organic compound identification
- Alcohol identification
- Identification of components of a mixture

Inorganic Preparation and Synthesis
- Preparation of tin compounds
- Racemic mixtures of transition metal complexes
- Synthesis of 4-cordinate transition metal

Organic preparation and synthesis

- Synthesis of dibenzalacetone
- Preparation of acetenilide
- Reduction of benzophenone to diphenylmethanol
- Benzylamine with benzoyl chloride
- Electrophilic substitution in aromatic compounds – preparation of Methyl 3 – nitrobenzoate
- The Schotten-Baumann reactions – preparation of N-Phenyl benzene carboxamide
- Reduction of substituted acetophenones
- Reduction of methane
- Isolation of trimyristin from nutmeg
- Bromination of acetanilide
- Preparation of phenyl acetate
- Esterification and distillation of isoamyl acetate
- Dehydration of t-amyl alcohol

complexes

- Characterisation of a copper oxalate complex
- Boron Chemistry
- Chemistry of co-ordination compounds – preparation and analysis of potassium tris oxalate aluminate

Techniques

- Filtrations: including vacuum, gravity
- Quickfit glassware: reflux, distillation
- Use of vacuum dessicator
- Separation of a mix of compounds
- Sublimation (a simple form)
- Stirrer, hotplate and steambath use
- Use of pipettes
- Rotary evaporator
- Melting points
- Keeping lab diaries and lab books

Unique first year activities

- MagnetoChemistry
- Linear free-energy relationships
- Mini research project poster
- Experimental design
- Column chromatography
- Distillation
- Electrochemical cells
- NMR (nuclear magnetic resonance)
- Vacuum line technique
- Microwave synthesis
- ILP – interactive lab primer: video clips/ animations/ theory/ HASDAN/ general lab info. Students guided to look/ research before lab
- PBL (problem based learning)

4.3 Physics first year activities

The groups agreed that the purpose of labs in first year is often to develop a set of skills that can be taken into subsequent years, as well as introducing students to the Physics. There was considerable overlap in activities, which came as little surprise to the groups:

Approaches were mixed in terms of whether the labs themselves were linked to lecture content, for many the numbers for students and amount of equipment meant this was not possible. In the first term, one institution covers A Level Physics but in the style of a university lab, as they found that doing both university Physics in the university lab was overwhelming for students. It was noted by some that skills sessions could be boring for students, and that it was necessary to explain the purpose of these activities.

While they talked about the skills they hoped students would develop, in most of the discussions the experiments were grouped by areas of Physics, rather than sets of skills. Most had students work in pairs in first year, and ways of organising this were varied. A few had students keep the same partner, while others were assigned new groups or pairs for each session. One participant noted that institutions like the IOP tended to encourage them to have their students develop group working skills.

Shared first year activities

Mechanics

- Hooke's Law
- Simple harmonic motion
- Moment of inertia
- Pendulum errors
- Simple pendulum
- Rotary oscillator
- Coupled Pendulums
- Measuring G

Thermodynamics

- Stefan's Law
- Latent heat of liquid nitrogen
- Planck's constant
- Boltzmann's constant
- Gas flow
- LIN (density & latent heat)

Astro

- Astro observations
- Cosmic rays
- Telescopy
- Lab View computerised data collection
- Hubble's constant
- Redshift 7

Modern

- Hall effect
- Rutherford scattering
- Attenuation of gamma rays
- Millikan's oil drop
- Michelson-Morley
- e/m
- Spectrometer
- X-ray (Bragg)
- Photoelectric effect
- Beta-particles and gamma-rays

Non-optical waves

- Vibrations of a ? plate
- Speed of sound demonstrated
- Standing waves
- Studies of acoustic wave integration Young's slits
- Sonometer
- Forced oscillations

Optics

- Speed of light
- Lens optics
- Laser optics
- Microwave optics
- Interference
- Newton's Rings
- Geometric optics
- Frauhofer Optics
- Single photon interference
- Spectroscopy of hydrogen
- Geometric magnetic fields
- Michelson Interferometer

Circuits

- DC circuits
- AC circuits
- Basic oscilloscope (LCR)
- Alternating circuits
- Analogue electronics
- Electrical resonance
- Ohm's law and beyond
- Electrostatics
- Inductance (DC)
- Digital electronics – frequency counter, capacitance meter, Geiger counter
- LCR basic radio

Physics techniques

- Random errors
- Manual timing
- Data analysis
- Systematic errors
- Calculating errors
- Basic test eqpt – oscilloscopes, multimeters, micrometers…
- Basic electronic eqpt – use of CRO, Signal generator, breadboards
- Basic use of an optics bench – lenses, diffraction gratings
- Precision /measuring experiments
- Writing a lab report
- Using graph plotting software
- Hypothesis testing
- Computing Matlab, Excel, HTML

Unique first year activities

Circuits

- ELVIS (lab View)
- Black boxes – mystery electrical components
- Transients in comparative circuits

Electrostatics

- Coulomb's Law

Miscellaneous –specific

- Earth's magnetic field
- Materials moduli
- Ultrasonics
- Speed of sound

Mechanics

- Projectile (error estimates)
- Kater's pendulum

Thermodynamics

- Thermal radiation
- Ideal Gas Law
- Adiabatic expansion

Astro

- Solar telescope
- Radio astronomy
- Globular clusters
- Quasars

Other

- Mini-projects
- Business game – enterprise skills
- First lab is 'mission to Mars' – problem solving
- Week-long invention project after exams
- Skill of hand task – produce a simple radio receiver

- Investigating semiconductors
- Cp/Cv
- Latent heat of N2
- Conductivity (semis)
- X-ray diffraction (atomic structure)
- Newton's Law
- Poiseullie's Law
- Newton's constant
- Relative Kinematrics
- Conservation of momentum
- Cov/emc balance
- Acoustic interference
- Spectroscopy of Hydrogen (+Mercury)
- Electron Beams
- Magnetic Fields

5 Skills required for success in first year practical classes

5.1 Overview

There was considerable agreement across the focus groups in different disciplines on a set of core practical skills that were important for first year undergraduates to succeed. In addition to these, participants identified skills specific to their discipline that would help students get the most from their first year practicals.

The core skills are discussed first, in the approximate order of priority (most important first) that participants placed them in when asked to rank them in order of importance for new undergraduates. The specific skills are then discussed in Section 5.3. Overall trends are explored in Section 5.4.

5.2 Core practical skills

Workshop participants identified the following sets of generic practical skills as important for first year undergraduates' success:

- **Confidence and a positive attitude** in the lab or field, including students' engagement in their own learning;
- **Independent thinking**: the ability to solve problems independently in a practical context was desirable, but participants also wanted their students to follow instructions so there was some contradiction here;
- **Appreciation and application of scientific methods and practices**, including appropriate experimental planning, time management in the lab, observational skills, note-taking and scientific report-writing;
- **Numeracy** and mathematical skills, specifically the application of mathematical concepts in a practical context, data analysis and the ability to sense-check quantities and results;
- **The ability to work safely**, including awareness and use of safe practices was raised by all groups but especially prioritised by chemists;
- **IT skills**, especially in MS Excel, but also Word and PowerPoint;
- **Research and referencing**, including online and offline research skills, referencing and avoidance of plagiarism;
- **Communication, social and presentation skills** including collaborative working, IT skills and verbal presentation skills.

5.2.1 Confidence and attitudes

This theme was linked to the idea of students being able to 'think for themselves', which is included in the next section. It included engagement with practicals, willingness to learn and enthusiasm. An understanding of the context and relevance of labs was included here, as was students' willingness to take risks and learn from their mistakes. In the groups that discussed this, it was widely agreed that the sort of confidence and attitudes HE teachers would like to see in their new undergraduates was not coming through strongly with their intake in recent years, and was also seen to be in decline.

Over half of the groups felt that confidence and/or the right attitude towards practical work was crucial for success. Some groups described how this would underpin the development of all of the other skills listed. Confidence was seen as coming from experience in the lab and familiarity with experimental practices.. There was an expectation that the school system should have begun to equip students with this confidence that they could then apply in university practicals.

> *They have not done multiple experiments. [Students] need experience and competence, leading to confidence (Physics)*

Several participants described how a lack of confidence could lead to fear in the lab.

> *Lots of other things are linked to confidence; we need to 'waste' time to stop them fearing the lab (Physics)*

However, some also noted that too much confidence, or confidence that was not grounded in experience, could be detrimental to practical work at university:

> *Confidence is a double edged sword in that they think they can't be wrong or they go ahead and do something dangerous or stupid without having a clue that they are doing it. (Biosciences/Chemistry)*

Participants described approaches they used at university to foster confidence in the lab, but this was more often framed as changing practices that were seen as overly frustrating or intimidating for students.

> *Students can lack the ability to apply theory to practice. They don't have the confidence to get it done but like having someone there to double, triple or quadruple check. There is a reliance on demonstrators. [Students lack] self-belief. (Chemistry)*

Interestingly, this idea did not come through very strongly at all from the Bioscientists that were involved in the workshops. In one of the mixed groups, participants reflected on this difference:

> *[There is a] difference in confidence. Biology students seem happy to push buttons etc but Chemistry students are hesitant about handling glassware. (Biosciences/Chemistry)*

5.2.2 Independent thinking

This theme included ideas related to reasoning, critical analysis, self-awareness, problem solving and application of knowledge in new contexts (e.g. theory in a practical context), questioning why, but being able to understand and know when to follow instructions and ask questions. It was related to the confidence theme, but was framed more strongly around cognitive reasoning and making links, whereas the previous theme described more affective skills or attributes.

Chemists and bioscientists were most likely to prioritise problem-solving, while physicists tended to prioritise following instructions, although in discussion they also said that they would expect students to be able to troubleshoot issues before asking a demonstrator.

This set of skills was very highly rated as important. A few felt that independent thinking would be developed at university, but what they needed initially was an intake of students that were well able to follow instruction. The ideas in this theme were often rated as declining, and most of the groups said they saw little evidence that students had been taught this or that perhaps it had been taught but students struggled to apply their learning in a practical context.

> *Pigeonholing – they can only use their knowledge in one context, they can do it in a tutorial but not in a lab (Biosciences/Chemistry)*
>
> *Physicists expect to teach them technical skills what is surprising/disappointing is their lack of written communication skills and lack of resolve, lack of initiative, lack of ability to apply skills/knowledge (Physics)*
>
> *Taking responsibility for decisions, making decisions answering questions and not just following a recipe is important in both [disciplines]. However students should be able to follow a lab script or experimental protocol. (Chemistry/Physics)*

A few HE teachers reflected on their role in a student's education at the point where they move from following a prescriptive approach to developing their own questions and hypotheses:

> *There is an unresolved fundamental tension between us crushing/forcing them into a formal scientific structure versus later wanting to open them up and adopt a questioning/thinking approach to experiments. (Physics)*

The tension described above was evident in some of the discussions. In one group, the notion that it might be better if practical work was omitted completely at school was put forward, although after some exploration it was soon agreed that this would not be a beneficial approach. HE teachers often expressed frustration that they did not fully understand what they could expect their new undergraduates to come in with regarding practical skills; even those that had gone so far as to observe practicals in local schools understood that it was not possible to generalise from one school when they were considering their whole student body.

5.2.3 Scientific methods and practice

This heading is used to bring together sets of skills about planning, doing and writing up practical work. It included constructing a hypothesis and experimental design, the practices of practical work such as time management and working alone, making, articulating and recording observations, writing up, and paying attention to both the process and outcome of the experiment. In Physics the appreciation of random and systematic errors was also raised in this context, as well as in the context of mathematical skills.

The many ideas discussed under this theme are grouped in the remainder of this section. Experimental design is discussed first, followed by carrying out practical work, then writing up.

- **Experimental design and purpose**

On the whole, workshop participants expected their first year undergraduate students to come with an awareness of experimental design, including constructing hypotheses and using controls. However, because most first year practicals were prescriptive, students did not need to design their own experiments. The ability to read and comprehend a lab script and follow the instructions it contained was therefore important (as described earlier).

Some experience of working in the lab is desirable – idea of controls and basic experimental design. (Biosciences)

Beyond these basic ideas, there was also a sense that students could misunderstand the purpose of practical work, or that their desire to gain marks could lead them to prioritise aspects of the practical that are not important, or omit crucial aspects. In discussions, this was often put forward in terms of the balance between process and outcome. Some felt that students would work towards getting any 'result' without recording or considering the quality of the process.

Students can feel pressured for time and feel that the only way to get marks is to get the 'right' answer. They need to capture what went wrong, errors etc. we need to communicate that it's the process we are marking not the 'success' of the experiment (Physics)

On the other hand, some felt that students expected to be rewarded marks for simply spending time doing the practical, without due attention to the quality of the experimental outcome.

Summarising – getting an answer, a conclusion, something noteworthy rather than just expecting to get marks because of the amount of time spent in the lab (Physics)

Overall, participants felt that their new undergraduates were increasingly mark-oriented and this was one area where they saw it being detrimental to what they were trying to teach in practical classes. However, many noted that these skills would be developed over the course of a degree and that they would not expect students to be well equipped

- **Carrying out practical work**

As described in the later sections about skills specific to disciplines, undergraduate teachers expected that they would develop students' skills in manipulating apparatus. Some mentioned students' observational skills as an area of concern during the workshops as these skills are important for success. However participants did not feel that these skills were improving or declining.

Observational skills – it's more than just looking, they need to be able to look down a microscope and observe, to know what you're looking at. That's the scientific stuff, the analysis and interpretation, the higher level stuff. (Biosciences)

They seem at a loss when asked to observe reactions – they say 'I don't know what to say' (Chemistry)

Time management during practical classes was mentioned by a few participants, who felt that because school experiments tended to be much shorter this was not something students had needed to consider previously. Of those who discussed this, most felt it was not a concern for first years, and would be developed in time for project work later in the degree.

A number of groups discussed recording observations in lab books. Most did not expect lab books to have been used at school:

Lab books are one area which is not taught at all at school, report writing is not taught either. Students don't know how to make or record an observation. (Chemistry/Physics)

Report writing will be discussed next, and it was noted that some students found it difficult to distinguish between a lab book and a lab report. A few participants had anecdotes about students noting observations on scraps of paper then 'copying them up' neatly into their lab books.

Lab books are not understood. They can be legal documents in industry. [Our institutions] do not allow lab books to leave the lab as in industry, which helps students understand their purpose and to differentiate between lab books and reports. (Physics)

- **Writing up**

While undergraduate practical teachers felt that an awareness of experimental design and some skills in carrying out practical work were desirable, they were much stronger in their views about students' writing up skills. They felt that their first year undergraduates should come equipped with the ability to write up an experiment in the appropriate scientific style.

Scientific writing was the area that Chemists and Physicists felt was of the highest priority and least in evidence in their student intake, although Bioscientists felt their students were better equipped with this. Participants from all three disciplines felt that scientific writing skills were in decline among their new undergraduates.

They are not taught to write in a scientific style at A level, this would be a useful thing to include – it could be quite prescriptive. (Chemistry)

Participants also noted that it is not just the science curriculum that supports this:

Scientific writing is a problem. When I refer to them needing to use the third person, overseas students understand what I mean but UK students don't so the issue is not just scientific literacy it is a more fundamental issue about grammar. (Physics)

- **Scientific approach or 'philosophy'**

As well as looking at the individual skills that formed part of the overall 'scientific method' theme, some groups felt that what they were looking for in their prospective students was an overarching scientific approach or, as some of the physicists termed it, a 'scientific philosophy'. This was about taking a disinterested, objective approach to testing hypotheses and using their skills in this context.

Essentially we are talking about transferable skills, but we are talking about those skills applied in a scientific laboratory context (Biosciences/Chemistry)

It was felt that this overall approach would be developed over the course of the degree, but that students should come equipped with the building blocks (especially in writing).

They will acquire scientific method over the course of their degree (Biosciences/Chemistry)

5.2.4 Application of numeracy and mathematics

This broad skill set related to students' ability to apply quantitative ideas and techniques in a practical setting. It included understanding the difference between accuracy and precision, an appreciation of errors and the ability to plot and interpret graphs. In Chemistry and Biochemical aspects of the Biosciences, additional numerical skills related to mass, molarity and yield calculations, while across the Biosciences participants felt students were poorly equipped to use units, powers and logarithms. A number of participants also felt that these types of skills were declining.

Generally speaking, physicists thought that Maths had been taught and that students could use it. The concerns were about applying the Maths in a practical context, rather than students' mathematical ability. This was not seen as a large concern compared with other issues for the physicists, largely because Maths is usually a pre-requisite for a Physics degree and many students had also studied Further Maths.

> *Maths* per se *is not an issue but Maths applied to Physics is. It may be down to whether or not they've done Further Maths. There is an issue of understanding applications for everyone but it may be less of an issue for those who've done Further Maths. (Physics)*

Numeracy was a much bigger concern for Chemists and Bioscientists. Chemists were unsure about what was taught in school in this regard, but it was seen as important and relevant to the lab. There was a difference for different institutions because some require A Level Maths for the Chemistry course, while others run the practicals as part of broader dual honours or Natural Sciences courses.

> *In Chemistry it is more about having a facility with numbers so they can use them in the lab. (Chemistry)*
>
> *With the Maths there can be a lack of the self-check in students' heads – you have just added two things how can the result be smaller than what you started with? (Chemistry)*

Numerical skills were thought to be important in the Biosciences, but declining significantly. Data analysis specifically was seen as less of a priority (although still important) and having a less strong decline. However, universities are less likely to require an A level in Maths for entry to the Biosciences as opposed to Physics, which is likely to explain why this is ranked more highly here than for physicists.

> *Quantification and measurement, the importance of working quantifiably in science. The importance of working accurately. Understanding the limits of accuracy e.g. that 6dps are meaningless. Precision, also self-checking. Numeracy is declining slowly and steadily, evidenced from our experience of running practicals and what students find difficult. (Biosciences)*

It was also noted that statistics is part of Biology A Level, so participants felt that new undergraduates came to university fairly well equipped in this regard. Some Biosciences degrees do not require A Level Chemistry and consequently students could struggle with some numerical aspects of lab work.

Numeracy stands out as the one that Biologists think is more important than Chemists do, but that may be down to subject requirements. Bio courses are more likely to be taking students without Maths A Level or even three sciences. (Biosciences/Chemistry)

Many of the participants felt that students' IT skills were improving (discussed later in this section) but were keen to point out that this did not necessarily mean that their understanding of the mathematical concepts had improved.

Excel – A Level Physics is not going to test that. But the danger is that they produce a graph without thinking about the science. (Physics)

5.2.5 The ability to work safely

This was only included on the matrix by chemists, although most of the groups referred to safety in their discussions. This included safe practice in the lab, a 'professional attitude' to safety and risk assessments and COSHH forms. It was seen as improving by some, but alongside this was a concern about a safety culture that could be fostering fear in the lab and inhibiting risk-taking too much. On the contrary, one of the physicists that participated in the workshops was concerned about a recent increase in accidents in the lab. Physicists and Bioscientists were more likely to link safety into ideas about students thinking for themselves or being confident in the lab, while chemists tended to consider it a separate skill set.

Safe conduct in the lab is important – not wearing your lab glasses on your head or wearing flip flops! (Biosciences)

We have students now who ask if they will be charged for breakages, which may be linked to Health and Safety culture. (Chemistry)

5.2.6 IT skills

On the whole, participants felt that their students' IT skills had improved greatly, especially their use of Excel, Word and PowerPoint. However, some participants felt that while students were familiar with Excel, they were not always able to use it to make meaning from scientific data. PowerPoint and Word skills were seen as improving, but not a priority.

Presentation and interpretation of results is linked to the Excel idea. They are better at using Excel than thinking about what it means. (Chemistry)

IT skills – we assume that youngsters are computer savvy and they're not. Also, [our university] has lots of mature students who are not (Biosciences)

Improvement in IT is focused on PowerPoint and Word rather than Excel – on qualitative not quantitative applications. (Biosciences)

One participant also felt that HE staff could assume students had a higher level of proficiency in these areas than was really the case.

5.2.7 Research and referencing (online and offline)

Participants felt that students were very able to research information on the internet, but were less good with the use of 'offline' sources such as textbooks. They also noted challenges around referencing/plagiarism and judging the quality or relevance of material found online.

While students now are much better at finding information online, they are not so good at checking the relevance of sources or knowing which sources can be trusted. Wikipedia is a good starting point but shouldn't be relied on alone! (Chemistry)

All of these were seen as important to HE staff in Chemistry and Biosciences, but physicists did not prioritise them so highly. Online research skills were seen to be improving, while skills in more traditional 'offline' methods were seen as declining.

5.2.8 Communication and social skills

This theme excludes written communication, which was grouped under the 'scientific method' idea, but includes verbal communication, cooperation and teamworking, and presentation skills. Findings in this section were very similar across the scientific disciplines, perhaps reflecting the more general nature of the skills described.

Some participants felt that current students are better able to communicate verbally than those in previous years, but this was contested: some felt that this was improving while others said it was in decline. Some felt that students were better equipped to work in groups or interact with others, but that they were not always able to communicate technical or scientific information effectively.

> *Students now are good at working together, they seem to do quite a lot of that at school and it relates to employability too. (Biosciences)*

As indicated in the quote above, participants realised that these skills were important to employers.

> *We are not just teaching them to be chemists, but to be successful in the workplace. (Chemistry)*

Presentation skills were also seen as improving, linked to an idea that students are asked to do this more at school. However this was seen as a lower priority for success in first year practicals.

5.3 Practical skills specific to disciplines

All of the groups identified skills specific to their scientific disciplines during the workshops. Groups did not tend to include these skills spontaneously, but more often after prompting from the facilitator and reflection on the lists of first year activities they had created.

5.3.1 Chemistry lab techniques

Lab *techniques* specific to Chemistry included: dexterity and manipulation, using glassware, burettes and titrations, accurate weighing, preparing solutions. The chemists also identified some specific *experiments* that would be beneficial for students to have conducted: synthesis of aspirin, melting point, recrystallization, and chromatography. Little or no change in students' proficiency with these skills was noted.

The general techniques were seen as fairly important (especially manipulation and dexterity) while the specific experiments were described as things that would be on the 'wish list' for A Level Chemistry. These would be covered at university so it was not deemed necessary to have a great deal of detail on them at school. In addition, the Chemists noted that many of their first year practicals required specialist equipment that would be well outside the budget of a normal school, so they would not expect students to have encountered it prior to university.

Generally first years have less practical skills because they do less. They don't get the exposure to glassware etc. they don't talk about it at school, and they don't develop the dexterity. (Chemistry)

One group described how teaching students that came in with some of these skills would differ from teaching students that had not encountered them:

If they have been taught the basics we wouldn't need to spend so much time on the basics e.g. if a student is familiar with the [burette] technique and has left the funnel in the top, a demonstrator can remind them to take it out, and they can recognise why. If a student is not familiar with the technique, we need to explain why the funnel should not be left in etc… it all takes up time on the basics that could be better spent extending students' learning. (Chemistry)

5.3.2 Physics instruments and equipment

In Physics, the specific skills related to familiarity with instruments and equipment that would be used in the Physics lab. The following instruments were listed: oscilloscope, stopwatch, Vernier scale, DC I/V source, AC signal generator, frequency counter, multimeters (I, V, R, AC/DC), simple circuits.

Two of the three groups of physicists rated these skills as very important, and one group felt they were less important because the skills would be developed during first year. However the groups did agree that these aspects were not being taught as much as other skills, although no improvement or decline was noted. In the mixed group of chemists and physicists, the differences in the specific techniques were discussed:

In Chemistry there is a definitive A Level experiment in the form of titration which it is reasonable to expect all students to be able to do. There is no such one definitive experiment for Physics.

For both subjects dexterity is important – handling glassware, twiddling knobs or pushing buttons.

(Chemistry/Physics)

5.3.3 Biosciences lab/field techniques

When asked about skills specific to the Biosciences, participants suggested: calibration curves, assays, spectrophotometry, pH buffers, weighing, microscopy, density, pipettes and field skills. An understanding of the purpose and relevance of the instruments was mentioned, as well as the techniques for using them.

All of these skills were rated as medium priority at most i.e. the core skills such as scientific method, numeracy and independent thought were seen as more important to success in first year. Participants thought that students had probably been taught some of the specific techniques, but were unsure whether they had the ability or confidence to apply them. Like the Chemists, the Bioscientists acknowledged that schools would not be expected to have access to university-level apparatus.

They should have done microscopes, otherwise we wouldn't have really expected them to have covered any of the specific skills. (Biosciences)

The group were also asked about fieldwork specifically, as this has particular importance in Biology. Generally undergraduate teachers assumed that little or no field skills would be developed through A Level, and expected to cover this at university level.

> *[They] don't do much [fieldwork] at school and we are happy to train them. There is a lack of funding at school for minibuses etc. to get them out of school to do fieldwork. (Biosciences)*

The workshop participants described little or no change in the levels of these skills among their new undergraduates.

5.4 Trends in skills

5.4.1 Overall rankings

The nine matrices produced during the focus groups were used to create the groups of skills explained in Section 5.3 above. Using the positions in which the skills were ranked on the grid the broader groups of skills were positioned on a similar matrix. The aim of this is to give an idea of the levels of priority undergraduate teachers place on each skill set, and the extent to which they feel the skills are in evidence among their undergraduate intake.

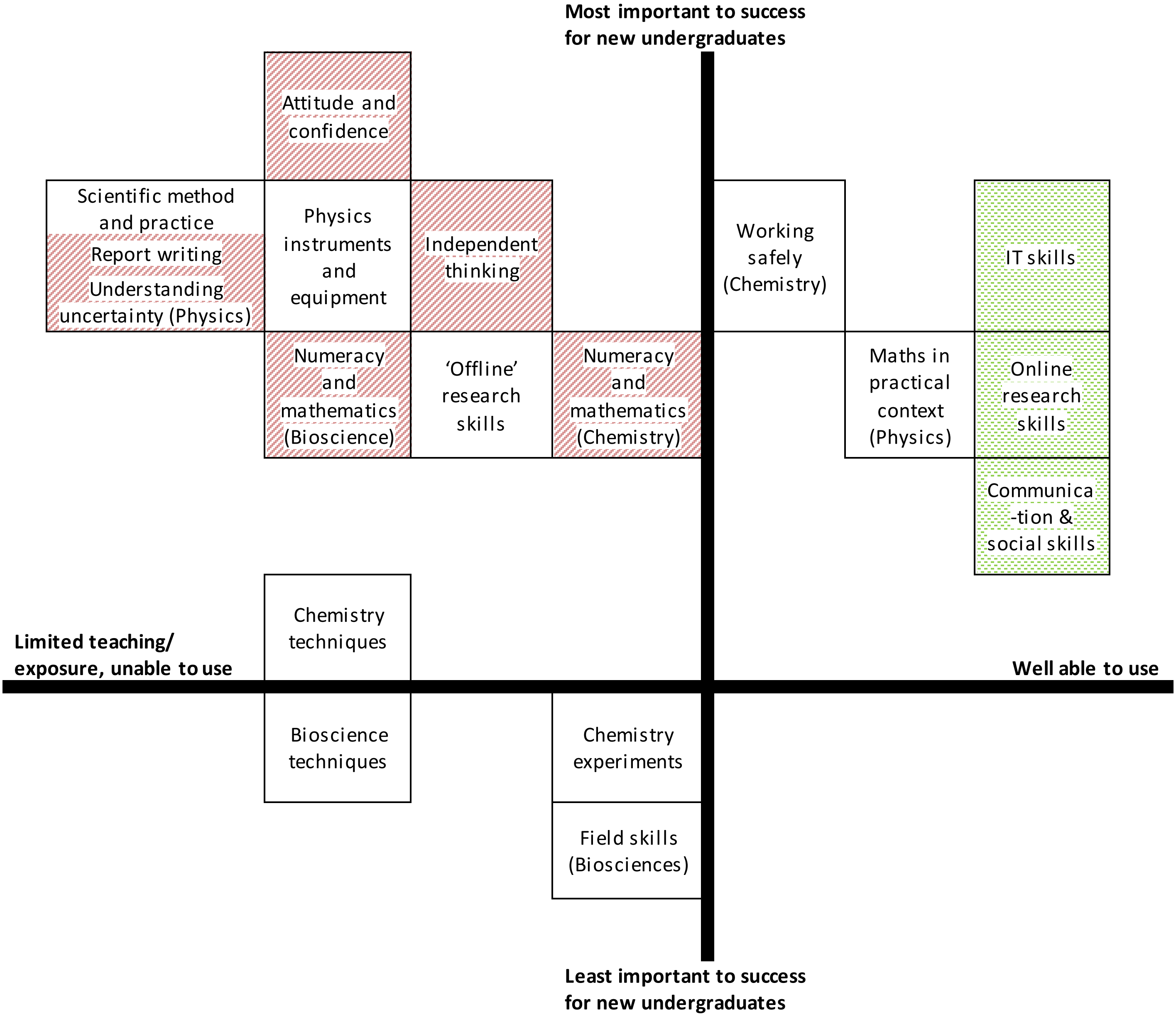
It is important to note that there were differences of opinion between groups, and also that some aspects of a skill set were sometimes seen as more important than others. This was taken into account when determining the position of each skill on the matrix. However the matrix provides a useful way to visualise the broad outcomes of some very detailed discussions. The overall matrix is provided below. The matrices produced by each focus group are provided in Appendix III.

Participants also explained that they were well able to rate which skills were important and less important, but that they were much less confident in assessing the extent to which students had been taught/exposed to the skill. This should be borne in mind when interpreting the results.

The skills that participants marked as improving or declining have been placed in shaded boxes. Those shaded with red stripes were those that were thought to be in decline by some or all groups. Those shaded with green spots were thought to be improving by some or all groups:

Denotes a skill that was rated as declining	Denotes a skill that was rated as improving

A framework that lists all of the skills identified by participants under each of the headings is provided in Appendix II.



There are a few striking trends in the rankings:

- There was enough similarity between the three disciplines to produce a common matrix.
- The core practical skills and attributes were more highly prioritised than skills specific to scientific disciplines. The exception is the use of Physics equipment. Chemists and Bioscientists expected that students would develop these skills throughout university.
- The core skills were also the ones that were seen as either declining or improving. Participants tended to feel that the more important skills were in decline, and those that were less important were improving. These changes were widely stated as having taken place over the last 10-15 years, although two participants commented specifically that there had been a sharp decline affecting the undergraduates in their 2010/11 intake.
- The extent to which students are well-equipped with numeracy skills varied considerably between the disciplines.

Those skills that participants placed in the lower two quadrants were described as ones that would be 'nice to have' but that would be taught at university.

When reflecting on the skills they had prioritised, participants pointed out that they would be difficult to teach and assess at A Level. As described earlier, it was felt that skills such as independent thought and confidence would only come from experience of practical work.

> *A Levels don't assess the skills in the top quadrant so the issue is not whether [skills are] declining or improving but whether they are taught or encountered at all. (Chemistry)*

It was also agreed that some of the more transferable skills would be developed in places other than science A Levels.

> *We need to remember that some of the skills we've described – like grammar and presentation skills come from outside the science curriculum. (Physics)*

5.4.2 Evidence base

Teaching Fellows (academic staff whose roles focus on teaching and do not include research) were well represented at the workshops, and some described how this move towards having more university staff with a focus on teaching meant that skills levels were being taken into account more effectively.

> *Lots of us now are employed just to teach, so we are more involved. Ten years ago there was a smaller proportion of people teaching full time. (Chemistry)*

With some exceptions, it was obvious from the workshop discussions that university staff, other than those who are former school teachers, obtained their information about what is being taught at A Level from their students.

> *Our students tell us they have done no practical work [at A Level]. We have no evidence to the contrary so base our practicals on what we've been told. (Physics)*
>
> *An appreciation of what they come with would be helpful – they need the mindset to be able to make links, put their learning into another context. (Biosciences/Chemistry)*

There appeared to be no formal channels for them to find out from other sources. Some groups discussed how they had read the various A Level syllabi, but could not deduce exactly how much practical work was included.

> *We looked at the A Level syllabus but if they come equipped with everything on that they will have already done two thirds of the degree! (Biosciences)*

As a consequence there was a widespread view that the universities' relationships with the exam boards and schools need to be strengthened, in order for decisions about course content to be better informed.

5.4.3 Perceptions about the school system

Discussions at the workshops revealed a range of perceptions that HE teachers held about the school system.

- **Practical content of the A Level syllabus**

Based on student feedback, many HE teachers felt that schools were covering less practical work at A Level and moving more towards demonstrations. Even when students had experience of hands-on work, one group felt that the purpose was still to demonstrate a phenomenon, or validate what had been taught, rather than experimental investigation.

> *The emphasis of school experiments is to validate what is being taught. They get worried if they think they will lose marks. They have not been exposed to what we would call experiments, but demonstrations of experimental phenomena. It would be good to distinguish these and use the right terminology. (Physics)*

Another group commented that students who had completed an extended investigation as part of their A Level appeared better equipped for university practical work. The lack of time in school practicals was seen as a factor that limited the development of investigative skills:

> *I have no idea about what they are learning in school. The trouble is that the curriculum is so full that they don't have the opportunity to experiment in the school working day. Most experiments are rigid with a known outcome. (Biosciences)*

Undergraduate teachers were unsure what equipment was available in schools, and felt it would be useful to know this. They also discussed how varied teaching could be. There was a perception that a significant proportion of students were taught A Level Chemistry or Physics by non-specialist teachers.

> *The lack of Physics specialists means less practical e.g. radioactivity practicals have gone right down the chute. The teacher needs to be confident. (Physics)*

- **Purpose of A levels**

Some also discussed the purpose of Science A Levels, in preparing students for a range of future options, not just science degrees, and that everything included in the curriculum would be a trade-off with something else.

There were concerns among the workshop participants that students were being increasingly 'spoon-fed' which was limiting the development of skills related to independent thought and problem solving. Some felt that this approach was now being continued into university teaching:

> *We complain that they are spoon-fed, then we carry on spoon-feeding them… (Chemistry)*
>
> *What is being taught is not useful. They are taught rote learning and not application or how to work things out. (Biosciences/Chemistry)*

- **Modularisation and assessment**

Modularisation was seen as limiting the extent to which students could make links between different areas of a subject (seen as essential if they were to be able to apply their theoretical knowledge in the lab or field).

> *Modularisation and retakes makes it easier and fosters a short-term approach to learning. (Biosciences)*

Many participants also commented on how assessment-driven their current students are, and how this approach could undermine real learning. A focus on assessment at schools was also seen as restricting the amount of problem solving or interesting ideas that teachers could include.

> *They are mark-oriented which is true across all teaching not just in the lab. (Chemistry)*

6 Implications for and responses by universities

6.1 Overview

Workshop participants discussed the issues of practical skills for their universities and higher education in general. Their discussions identified a number of themes, namely:

- **Implications –** are practical skills an important issue for universities? What are the impacts on course structure or duration?
- **Practices and responses –** how are universities reacting to ensure their students receive effective training and education in the use and application of practical skills?
- **Other influencing factors –** what factors, other than skills, can influence the design and content of undergraduate practical sessions?

6.2 Implications

6.2.1 Practical skills: a problem?

Most of the groups said that the practical skills of their entry level students are an issue. While most felt that the issue was one they could cope with through their undergraduate teaching, it was widely acknowledged that the potential depth of the university-level practical learning was compromised.

> *It's a problem. We are continually adapting to the students that are coming in. We have cut down the number of experiments … the first term and a half is stuff that they would have come in with 10 or 15 years ago (Physics)*

> *We could push them further at the end if they came better equipped (Chemistry)*

Furthermore, some were concerned that if trends continued university science departments may no longer be able to adapt.

> *At the moment it is workable, but if trends increase we are in trouble (Chemistry/Biosciences)*

6.2.2 Assumed starting point

Many participants began the discussion by saying that they assume their new undergraduates will come in with limited or no practical skills. Some had noticed that in interviews, where ten years ago they could ask every student to describe a practical they had done, now only half of the interviewees could answer this.

> *Over the years the practical courses have developed to assume that students have no practical experience, we have to assume a base level of zero. (Chemistry)*

> *We assume they don't turn up with any skills (Physics)*

However some described how the view of teachers in HE would probably be different to the views of the students themselves.

> *I think that students would report themselves as having most of these skills (Physics)*

Groups also highlighted that their student body had become more diverse, due to students coming in with a wider range of qualifications, a perceived widening of the gap between the best and worst schools and teachers, and the recruitment of mature and/or international students. When prompted on which skills they would like to see included in the A Level specification, many responded with the caveat that changes affecting those that had been through the A Level system would only influence a proportion of the total undergraduate cohort. This meant that any such changes might be unlikely to make a difference to HE teaching practice (although they would help those students gain more from their HE experience).

> *Those from well-resourced schools are good because these skills depend on having access to the right equipment. Although sometimes having done it before is a disadvantage because then they think they know all about it! (Biosciences)*

The difficulty in differentiating between students at the admissions stage when so many achieve the top grades was also raised.

> *It's very varied between students, which is an issue. [It] has become more diverse over the years and we have backed off to go to the lowest common denominator. The gap is wider – there are still enthusiastic teachers that do extensive work. The extremes mean that the intake is wider plus it's difficult to differentiate between students – asking for 3 A*s is not a guarantee (Physics)*

6.2.3 Wider implications

Groups at all of the workshops discussed wider implications of issues around practical skills including those for employers and the changing situation with regard to student fees. There was a widely held view that more students are seeing undergraduate degrees as a route to a job. This results in students wanting transferable and generic skills which are required by employers.

> *There is a difference between training research scientists and training people to get any job – the focus for most students is the latter. (Physics)*
>
> *Our alumni tell us they would like to have had more communication skills, especially presentation skills and transferable skills. (Biosciences/Chemistry)*

The groups discussed how introduction of student fees could mean that students are more likely to expect to be taught transferable skills. Some groups also mentioned how the needs of employers are informing course content:

> *The first year programme is guided by who orders us, the QAA and benchmarking, employability standards. Biology is so varied and we also need to consider field skills which are valued by employers. (Biosciences)*
>
> *Fundamentally universities need to be in a position where they could take students further and meet employers' needs more effectively. (Physics)*

6.3 Practices and responses

Workshop participant described a variety of ways in which universities are taking action to enhance students' practical skills. Their responses can be broadly categorised as:

- Focus on skills development
- Course structure including pre-labs and project work
- Training for teachers and demonstrators
- Assessment methods
- Outreach

6.3.1 Focus on skills development

Participants described first year practical sessions that focus on skills development rather than new scientific knowledge. These skills sessions tend to be timetabled in the first semester and in many cases they use techniques or scientific theories which will have been studied at A Level. This was not necessarily a new practice, but it was described as important for students' success in later stages of their degrees.

> *We use titrations to build confidence and get them familiar with our practices. It is easier to teach them the logic and reasoning skills and thinking for themselves. (Chemistry)*

> *We do a one week intensive course on numeracy for students without A Level maths. It is geared to teaching them how to apply their maths in a scientific context. Those who do it are often better performers than the ones with A Level maths. (Biosciences)*

There were various practices that had been developed to address students' difficulties with mathematical aspects of Chemistry, from one-off workshops on graphs or errors to 'maths for chemists' boot camps for those without an A grade in A Level Maths. A related implication that was discussed to varying degrees at all the workshops was the dilemma of whether to reduce the amount of content to accommodate skills sessions or to maintain science content and add on skills sessions resulting in very intensive practical courses which could over-challenge students.

> *We assume that all the students are bright enough to cope with all the extra skills stuff we have had to include in first year practicals. Are they? (Physics)*

The groups described how the addition of skills content in first year practicals has a knock-on effect on later sessions and years.

> *We do the same experiments as before but in less depth as we cannot get to the same end-point as they [students] lack the basic skills. (Physics)*

Several groups also discussed how the introduction of four-year degrees has allowed for more time to be spent in the lab, although the additional time is often spent developing skills rather than additional science learning. As a consequence universities find they are having to review their course content in respect of progression from laboratory sessions in year one through to the end of degrees. Three groups included those with the opinion that the current four year degrees are effectively the equivalent of the old three year degrees.

> *[It] takes 4 years for an MPhys, but the most focused students don't want to waste a year and go straight from the BSc to a PhD. In Physics we have shifted it all one year on, so the old BSc is the equivalent of the current MPhys. (Physics)*

We have created four year degrees to compensate. We get to the same end-point but need more time. (Biosciences/Chemistry)

MPhys and MChem have devalued the BSc which could be a disaster. You can still get a successful PhD from a BSc. (Chemistry/Physics)

One group discussed the implications for joint honours courses where students could go on to take a PhD in a science in which they have essentially only done half a degree.

6.3.2 Structure of practical courses

Several responses to issues related to skills had resulted in adaptations to practical course structures.

Many groups discussed pre-lab sessions, which some departments were implementing. These tended to be most formalised in Chemistry departments, where for some the marks count towards the first year assessment. Less common but discussed in a number of groups was the inclusion of mini-projects at the end of the first year to aid the transition from learning skills to practising experimental science.

People were finding that students weren't coming prepared… We do assessed pre-work, observations and questioning within the lab. The difference we hear about – anecdotal feedback – is that students feel better equipped. The pre lab is not just about a test but is designed to be interactive and let students learn. (Biosciences/Chemistry)

Several participants also talked about reducing the number of experiments in first year in order that they could be covered in greater depth.

We have halved the number of experiments we do but expect better quality (Physics)

Some groups also discussed more strategic approaches adopted by particular universities, which have led to rethinking of how practical sessions are planned and delivered.

We looked at what we want to produce at the end – noted 5 key attributes: knowledge and understanding; communication; problem solving; project management etc. and make sure they are all taught through the course to produce 'marketable' graduate, link to employability. (Biosciences)

We have developed a starred system which enables students to understand the purpose of a particular session. We give different learning objectives up to 5 stars so they and we understand the purpose of each session. (Physics)

6.3.3 Support and training for practical teachers

Training for teachers and demonstrators varies from none to subject specific professional development courses designed in conjunction with Schools of Education or other education professionals. This variation is interesting given the importance the groups assigned to the laboratory experience when discussing what happens at A Level. One group said that whilst new lecturers received training for teaching, those who were already in post did not receive the same training. Universities are more likely to train their demonstrators than their lecturers, but there is still a problem in ensuring they receive the correct information in a systematic way and do not rely on custom and practice. One department had developed a wiki to capture demonstrators' tips and suggestions for particular practicals:

We set up a wiki to try and create a body of information like good questions, which captures the collective information if demonstrator turnover is high. We get lots of readers but not so many contributors… (Physics)

Key points from the discussions about the type of training and skills required by demonstrators are summarised in these quotes.

It is important to recognise that demonstrators can sometimes pass on bad habits. It should not be assumed that because they are a postgrad they can keep a good lab book. (Physics)

We actually need good communicators who do more than just demonstrating something. They must be able to give good written and verbal feedback. I wonder how many of us do more training than just training them to do the demonstration. (Biosciences/Chemistry)

Inputs from educationalists and schools vary between universities and subjects. Two groups included former school teachers or former further education lecturers who are able to inform the teaching process with their knowledge and experience. Teaching Fellows and other specialist university teachers are often required to have formal training which means their input is based on educational theory as well as practical experience.

6.3.4 Assessment methods

One factor that universities have reviewed is their assessment methods. Some groups talked about a shift away from lengthy write-ups to them being assessed by a combination of outputs from experiments and verbal questioning. Other groups were adamant that the write-up is important as it relates to the way in which scientific papers are written and is important for those wanting to be professional scientists. There was debate in several groups about students' concerns around consistency of marking, particularly when demonstrators or lab supervisors are marking. Another area that received attention was the fact that students are perceived to be very concerned about their marks, particularly if first year marks count towards the final degree award. Views ranged from those who believed that including first year marks in the final assessments could increase motivation and engagement to those who thought it would reinforce students' focus on marks which is perceived to be problem in that it increases the focus on getting the correct answer. Comments about assessment included:

Expectations seem to be changing. Students are driven by assessment and want to know where every mark went. (Physics)

I think that assessing pre-labs can be a good thing because it increases the student's motivations, but I guess we must be careful about reinforcing the idea that marks are the be all and end all. (Biosciences/Chemistry)

6.3.5 Outreach

Universities use outreach primarily to enthuse young people of school age and teachers about science. However for some, the links with schools developed during outreach activities were valuable in understanding the skills and needs of their student intake.

Some groups debated whether or not outreach activities that are designed to be exciting and engaging are representative of the reality of experimental science, which requires patience and observational skills. Not all the workshop participants said they are involved in outreach.

Those that are described a range of activities from school visits to practical sessions held in university laboratories for teachers and school pupils. One issue here is the number of schools that can be reached and the likelihood that only the most motivated teachers will get involved. Examples of outreach activities include:

> *I run sessions for teachers and pupils in the summer. They come into our labs which is an important factor in exposing them to real science. There also has to be some excitement too. (Physics)*
>
> *We have a good relationship with the local science learning centre. This helps us to reach-out to teachers. (Biosciences/Chemistry)*

6.4 Other influencing factors

Four groups said that students' practical skills and universities responses are influenced by a number of factors apart from A Levels. These included the amounts of funding, equipment and laboratory space that are available in schools and universities. At university level timetabling pressures and the enthusiasm of academic staff for practical sessions are also issues. The desire to link laboratory classes to lecture content was thought to be important, apart from two universities that have deliberately decoupled their practical sessions from the lecture schedule (for practical and logistical reasons) and who said they had received better feedback from students as a result. One of these also said they had increased the involvement of academic staff by reducing the amount of marking.

> *Lab skills are affected by various factors. Not just the practical content of the A Level curriculum. The number of students, amount of available equipment affects how and which labs are taught. (Chemistry/Physics)*
>
> *Academic staff don't rate practical teaching as it does not progress their careers. We need to change this to improve the profile of lab sessions. (Physics)*
>
> *Academic buy-in has been total. The Head of Department demonstrates on Friday afternoon. [Our approach] has removed the need to mark a huge quantity of write-ups or scripts. Result is more staff in the lab not taking home scripts to mark, which is good for the students and them. (Chemistry)*

Another influencing factor that was raised in several discussions and that was not unique to practical work was student satisfaction. With the introduction of higher student fees, the results of the National Student Survey were seen as increasingly important for some institutions. One participant described how their institution had dropped from a high ranking and this had translated into fewer applications the following year. There also appeared to be a stronger culture of student feedback in some institutions compared with others. One participant described having students complete questionnaires at the mid-point of each semester as well as at the end which led to pressure on academic teachers.

Academic teachers explained that while student satisfaction is important, learning is not always a comfortable or enjoyable process, and some felt that student feedback was given too much weight and that this would lead to courses becoming too 'easy' and 'fun', rather than equipping students with the knowledge and skills they need.

Students don't like it at the time, but later realise that they needed to cover the key techniques in Year 1… There's a difference between what they enjoy and what's good for them. (Physics)

Managing students' expectations and being clear about the purpose of skills-focused practical work in first year were practices that helped students (and teachers) understand why particular teaching approaches were taken.

We have developed a starred system which enables students to understand the purpose of a particular session. We give different learning objectives up to 5 stars so they and we understand the purpose of each session. (Physics)

7 Research questions and suggestions

Workshop participants were asked to identify areas of concern or areas that require further exploration in order to inform possible further research into how A Levels can best prepare young people for undergraduate courses in science. They identified a number of research questions and areas for deeper examination, as well as making some suggestions about strengthening relationships and improving mutual understanding between schools, exam boards and universities.

7.1 Questions

These fall into four categories around A Level course content, opinions of stakeholders, the relationship between universities and Exam Boards and support for A Level teachers.

7.1.1 A Level teaching

- What would be the likely impact in terms of practical skills of exam boards adopting a 'problem-based approach' in A Levels?
- What is the purpose of A Levels? How far should A Levels change to respond solely to the needs of university first year studies?
- How are A Level students taught? What opportunities do students have to think creatively and independently and to what extent are teachers teaching what they would like to teach at A Level?
- How well do teachers understand what is necessary to prepare students for university lab sessions as opposed what is necessary to get students to do to pass an exam? What support do they need to be able to respond to this challenge?
- How would it be possible to create a suitable teaching scheme for school pupils to acquire observational skills?
- Does the use of closed questions limit the ability of students to interpret experimental results (i.e. not to see the wider implications)? How does it affect understanding of scientific theories and concepts as opposed to facts?
- What is the best way to support theoretical learning through practical classes at A Level and university?

- How do practical skills vary between the different A Levels (e.g. Salters, Nuffield etc.) and other access qualifications or routes? What is the potential for exchanging best practice between the different qualifications?

7.1.2 Stakeholder opinions

- What skills do students (who have completed their first year) think they need in preparation for their university lab sessions?
- What are students' expectations of science courses at university?
- Where does university fit on the route from school to job? Why are students studying science at university?
- What do university tutors need to hear from A Level teachers so that they know what skills students have, rather than making assumptions or perceptions based on what the students tell them?
- What are the requirements of all stakeholders (including employers of all sizes) in terms of lab skills at A Level and beyond?

7.1.3 Relationships between universities and Awarding Bodies

- How does the interaction between exam boards and universities influence practical skills taught at both A Level and first year? What is the interaction between course designers and exam boards and how does this influence what is being taught in university practical sessions?
- How can universities best inform and influence exam boards and schools to ensure A Level students receive the best possible preparation for university?

7.1.4 Support for A Level teachers

- What resources, including interactive screen experiments, can be developed for schools to help them improve the opportunities to provide pupils with the experience of actually doing experiments?
- What are the skills gaps, including subject specialisms, amongst teachers that limit their ability to teach practical skills? How could these be addressed by universities and others in a systematic way?

7.2 Suggestions

The suggestions made during the workshops focus on two areas: seeking the opinions of other stakeholders (including other universities) and creating a forum for interaction amongst the different groups (including the different universities and universities and schools). With respect to the latter suggestion, participants had welcomed the opportunity to discuss practical skills that the workshops had offered.

7.2.1 Seeking the opinions of other stakeholders

- Get teachers, university staff and students who have completed first year together to discuss the issue of practical skills at A Level and university. It may be possible to invite these groups to complete the skills matrix used in the workshops.
- Conduct a survey of students when they start university, asking them what they think they are capable of doing. Also survey university teaching fellows and teaching staff, and school teachers to triangulate responses. Then repeat the survey at the end of the first term to see if their expectations matched reality.

7.2.2 Creating a forum for interaction

- Create a forum where universities can interact with one another about laboratory skills, including the sharing of best practice, on an on-going basis.
- Develop better interaction between University Science Departments and Schools of Education to ensure educational best practices are incorporated into lab teaching, e.g. training those who will teach students.
- Explore ways to reduce the gap of communication that exists between A Level teachers and university lecturers.

8 Feedback from engineers

8.1 Methodology

As described in Section 3.3, no engineers attended the workshops. Feedback from some engineering contacts suggested that the situation with engineering differs to the situation for the sciences, where it might be assumed there is more direct progression from school to university in terms of the practical skills taught in A Level science. By their nature the workshops were focused on science (as these are the A level courses the review will inform) and engineers felt that their colleagues might have failed to see such strong relevance to engineering.

In order to ensure that this report was not making assumptions, misrepresenting or simply omitting the views of the engineering community on this issue, representatives from six engineering professional bodies were invited to participate in a short interview about practical skills in the context of first year engineering undergraduates. Four interviewees from the Royal Academy of Engineering, the New Engineering Foundation, the Institution of Engineering and Technology and the Institution of Civil Engineers were able to participate in the study within the timeframe and their feedback is summarised in this Section.

Of course this is a small sample, so the interviews were exploratory and aimed to identify the extent to which practical skills of new undergraduates are an issue in the engineering community, to identify which types of skills are important for new undergraduates, and to suggest whether and how the engineering community might be involved in subsequent stages of the review.

8.2 Findings: practical skills of new engineering undergraduates

Interviewees from the engineering community agreed that practical skills of new undergraduates were an issue. However the issue was seen as around third in a list of priorities after maths – which was described as the top priority – and skills which the engineers did not spontaneously associated with practical work such as problem solving or physics ability.

> *It's the magic combination of maths plus physical science plus the practical element. (Engineering organisation)*

Many referred to evidence from employers, who felt that engineering graduates did not possess the necessary levels of practical skills to succeed in the workplace, and identified the school system as laying the foundations for this – although one questioned whether it was the role of the university system or employers to provide higher-level skills.

> *At the other end employers are talking about how undergraduates are coming out with very few practical skills. (Engineering organisation)*
>
> *Some would say isn't it down to employers to upskill? (Engineering organisation)*

When asked to suggest which practical skills engineers felt that new undergraduates would need to succeed, some listed skills that were raised by the scientists in the workshops, such as mathematical ability (highest priority), the ability to apply theories to a practical context, problem solving and transferable skills like communication.

> *Maths would be the biggest then a range of other things like computing, DT, problem solving, enabling skills like communication and writing… (Engineering organisation)*

In addition to these, specific skills were related to individual branches of engineering, so computing and electronic skills were relevant to electronic engineering, while sketching, making and hand-eye skills were seen as important in civil engineering. It was clear from the interviews that the understanding of what is meant by 'practical work' in engineering is different from that in the sciences, which may affect shared discourse on the issue as it relates to school education. One interviewee described the skills as 'an instinctive awareness' of how things would look and work in the real world.

The lack of linkages between sciences and maths at A Level were seen as undermining students' ability to apply their knowledge in practical contexts. Several also commented that the practical skills they would expect undergraduates to bring with them to university would perhaps come from a wider range of sources than for the sciences. DT and even art were important, as were vocational qualifications and extra-curricular opportunities (such as STEM clubs) and hobbies. Participants were concerned that the DT provision in school might be jeopardised in the proposed EBac qualification, and this would mean some students lost the opportunities to develop practical skills that are relevant to engineering.

> *They [employers] are going to be a bit fed up with D&T diminishing. [There is] a fear that practical will be missed out of the EBac etc, leading to a loss of awareness of design, art and making things. (Engineering organisation)*

Interviewees were keen to highlight that engineering courses are diverse with very different intakes, so like the sciences, any changes to science A Levels will only affect a proportion of students. More so than many colleagues in the sciences, engineering departments recruit students with a wide range of qualifications from within the UK and overseas. There are also often closer employer links with courses at some universities and HE in FE providers being closely linked to local industries.

One interviewee echoed some of the workshop participants in describing the motivations behind the creation of the MEng degree:

> *One of the reasons for MEng was a feeling that the first year was a catch-up with everything, a re-establishment of academic and practical skills. (Engineering organisation)*

8.3 Involving engineers in subsequent stages of the review

The Engineering HE landscape is very diverse and interviewees were keen to stress that any involvement of engineers in the current review should reflect this diversity. That is, a range of different HE institutions should be represented as well as a range of engineering disciplines. Several of the professional bodies suggested they might be a good place to start as they could work through their own contacts and networks. Several also suggested references and relevant reading that might inform the review (provided separately to this report).

APPENDIX I. List of participating institutions

Twenty-five universities participated in the research workshops.

Aston University
Bath Spa University
Cardiff University
Imperial College London
Keele University
Lancaster University
Middlesex University
Plymouth University
Queen Mary, University of London
Swansea University
University College London
University of Bristol
University of Cambridge
University of Central Lancashire
University of East London
University of Glamorgan
University of Leeds
University of Liverpool
University of Manchester
University of Oxford
University of Sheffield
University of Southampton
University of Sussex
University of Warwick
University of York

Particular thanks to the Universities of Bristol and Manchester, who kindly hosted workshops.

APPENDIX II. Practical skills framework

Confidence and a positive attitude	Confidence in the lab or field
	Prior experience of practical work
	Engagement in own learning, willingness to learn
	Willingness to make mistakes (and learn from them)
Independent thinking	Ability to solve problems/troubleshoot in a practical context
	Ability to understand and follow instructions
	Self-awareness during practical work: accuracy, judgement
	Ability to apply theoretical knowledge to practical context
	Thinking critically about an experiment
	Application of logic and reasoning in a practical context
	Ability to ask meaningful questions
Appreciation and application of scientific methods and practices	Awareness of effective experimental design
	Making and recording observations
	Keeping a lab book
	Time management in the lab
	Drawing conclusions
	Scientific writing
	Paying attention to both process and outcome of experiment
Numeracy and the application of mathematical concepts in a practical context	Identifying variables
	Sense-checking quantities and results
	Data analysis
	Drawing graphs
	Interpreting graphs
	Using units, powers and logarithms
	Statistics
	Awareness of errors, accuracy and precision
	Concentrations, dilutions, molarities (Chemistry)
	Yields and mass calculations (Chemistry)
The ability to work safely	Awareness and use of safe practices
	Respects but does not fear apparatus/chemicals
IT skills	MS Excel
	MS Word

	MS PowerPoint
Research and referencing	Online research skills
	‘Offline’ research skills including textbooks and journals
	Referencing and avoidance of plagiarism
Communication social and presentation skills	Verbal communication skills
	Presentation skills
	Team working
Chemistry lab techniques	Dexterity and ability to manipulate apparatus
	Use of glassware
	Burettes and titrations
	Accurate weighing
	Preparing solutions
Chemistry experiments (desirable for first year undergraduates to have undertaken)	Melting points
	Synthesis of aspirin
	Recrystallization
	Chromatography
Physics instruments and equipment.	Oscilloscope
	Stopwatch
	Vernier scale
	DC I/V source
	AC signal generator
	Frequency counter
	Multimeters (I, V, R, AC/DC)
	Simple circuits
Biosciences lab techniques	Calibration curves
	Assays
	Spectrophotometry
	pH buffers
	Weighing
	Microscopy
	Density
	Pipettes
Biosciences field skills	Field skills

APPENDIX III. Ranking of skills from focus groups

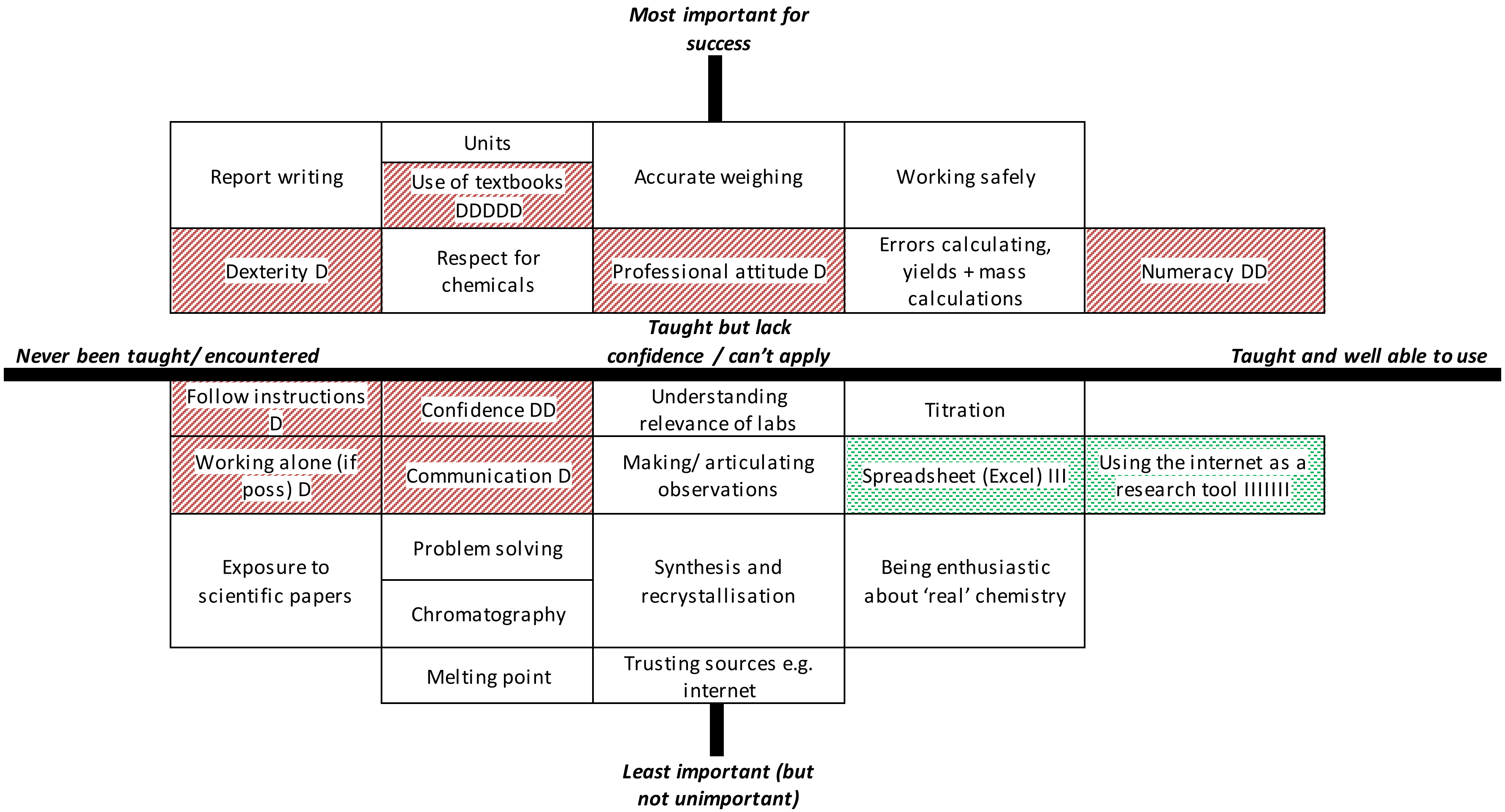
The charts on the following pages show the practical skills as they were listed by workshop participants, and the positions in which different groups placed the skills on the grids provided.

NB Red/striped cells denote skills that were rated as declining (D). Green/spotted cells denote skills that were rated as improving (I). The number of Ds or Is in the coloured cells gives the number of 'votes' attached to that skill. The horizontal axis is the same for all of the grids. Cells shaded grey denote that the skill was rated as both improving and declining.

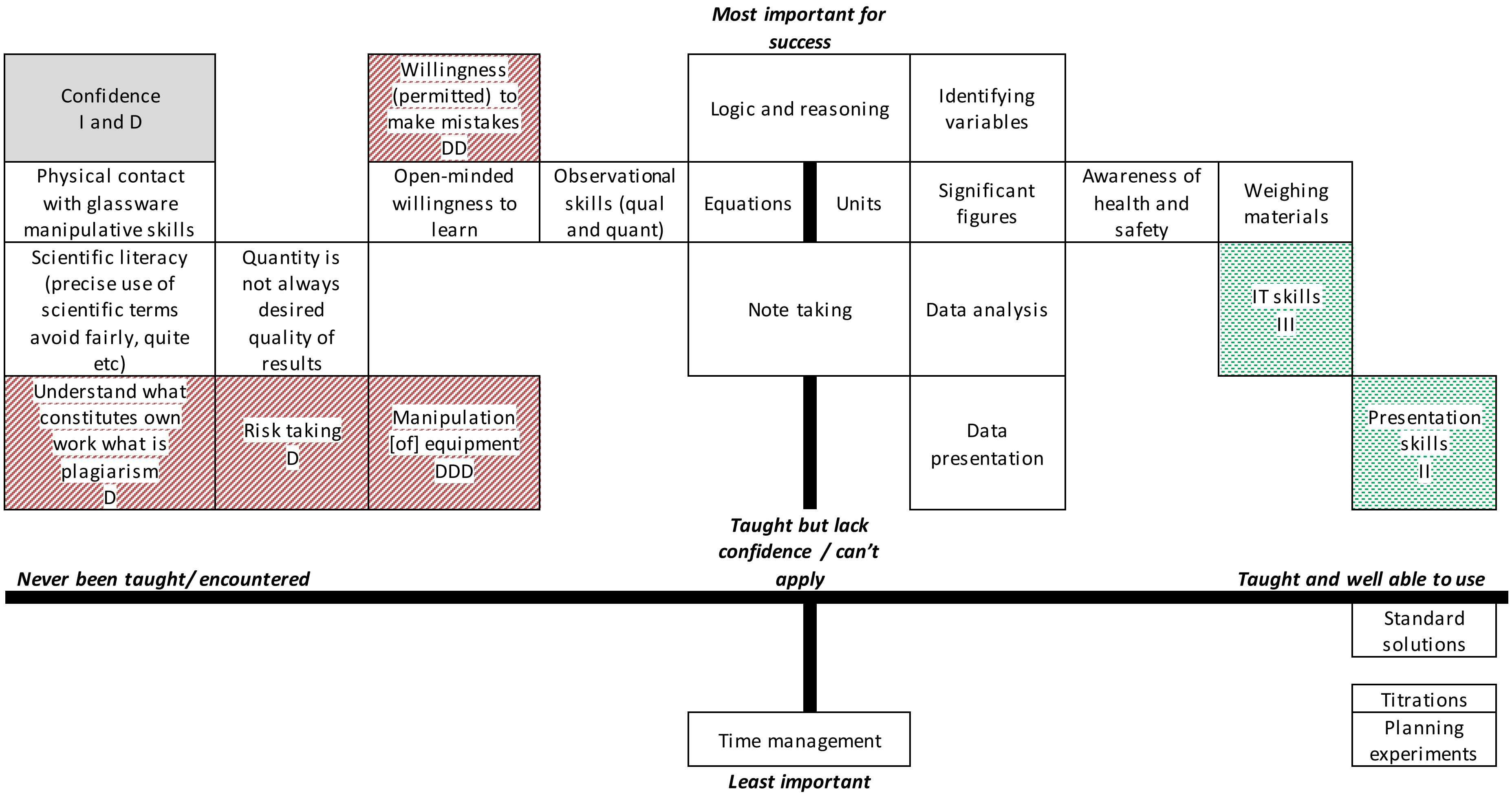
Denotes a skill that was rated as declining D	Denotes a skill that was rated as improving II	Denotes a skill that was rated as both improving and declining I and D

Axis labels are in ***bold italics***. The axes are represented slightly differently for the different matrices. This is because different groups positioned the skills in slightly different ways.

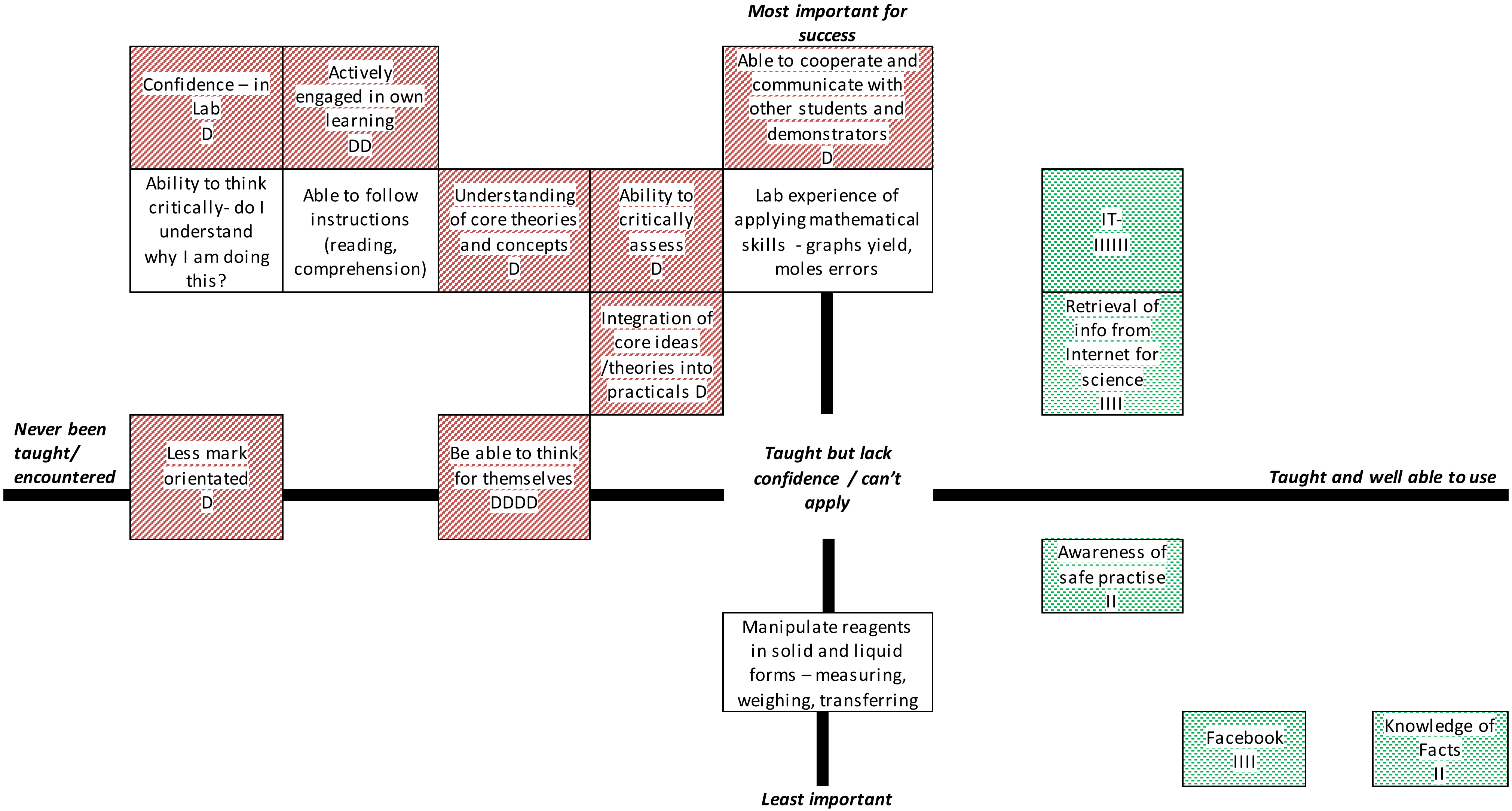
Chemistry group 1



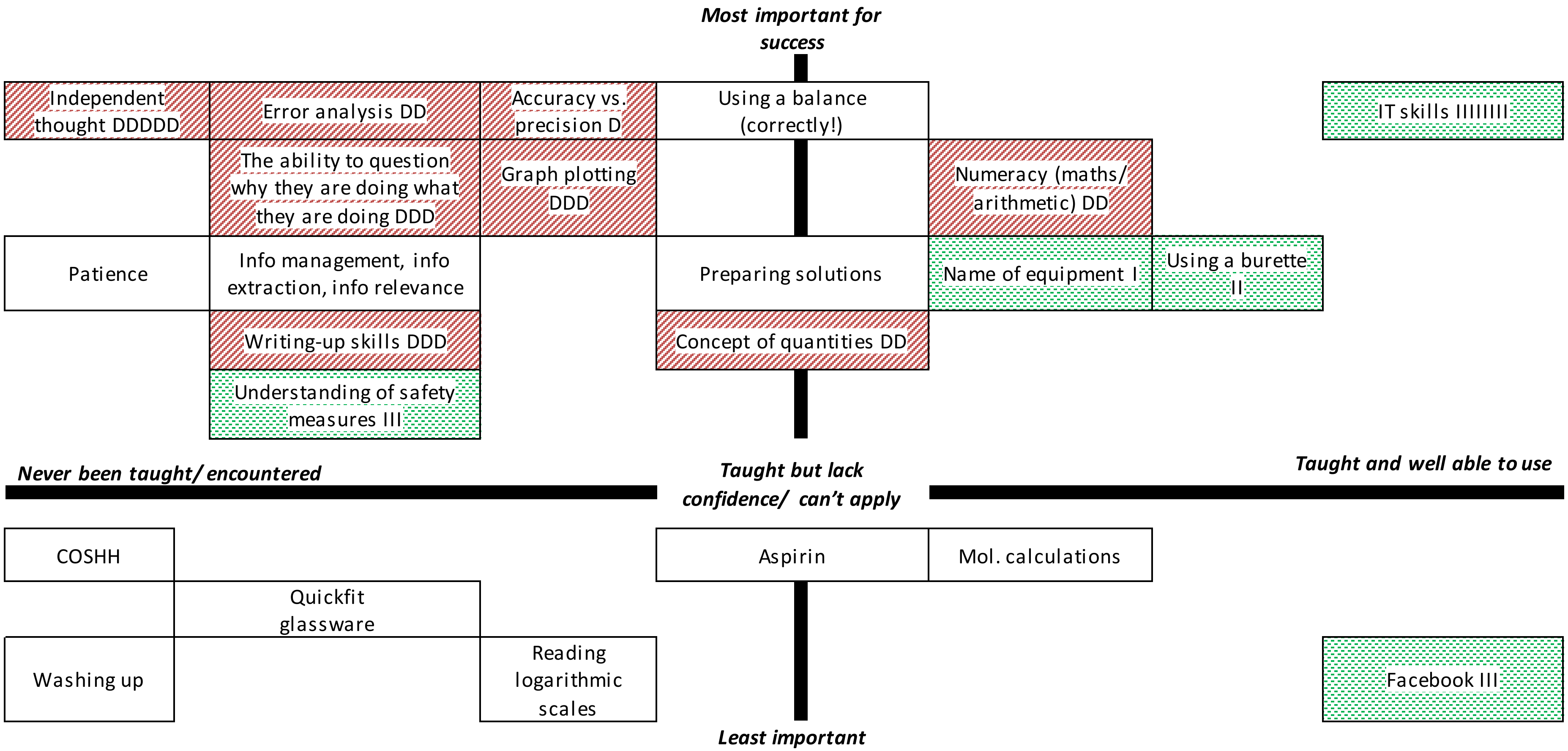
Chemistry group 2



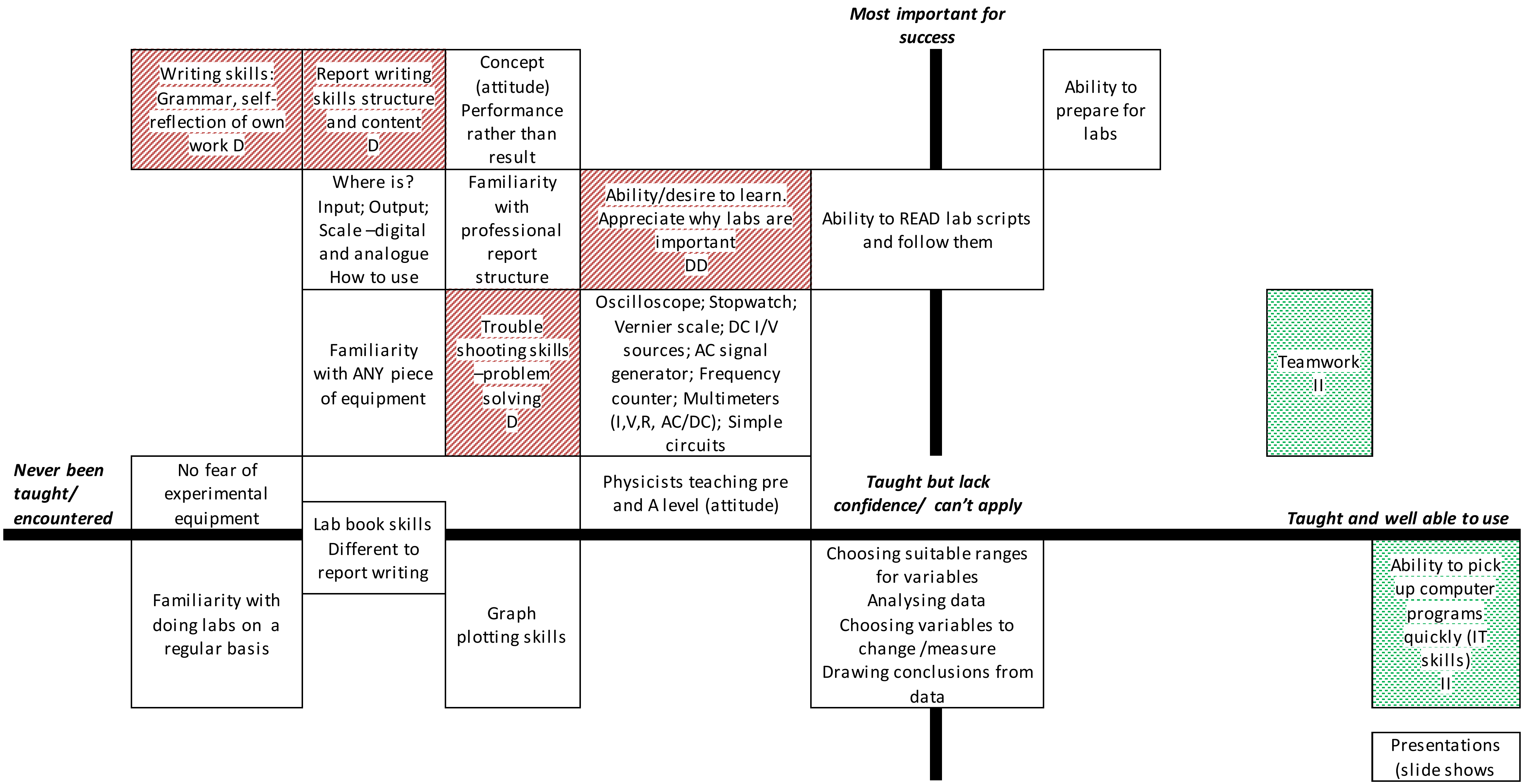
Chemistry group 3



Chemistry group 4



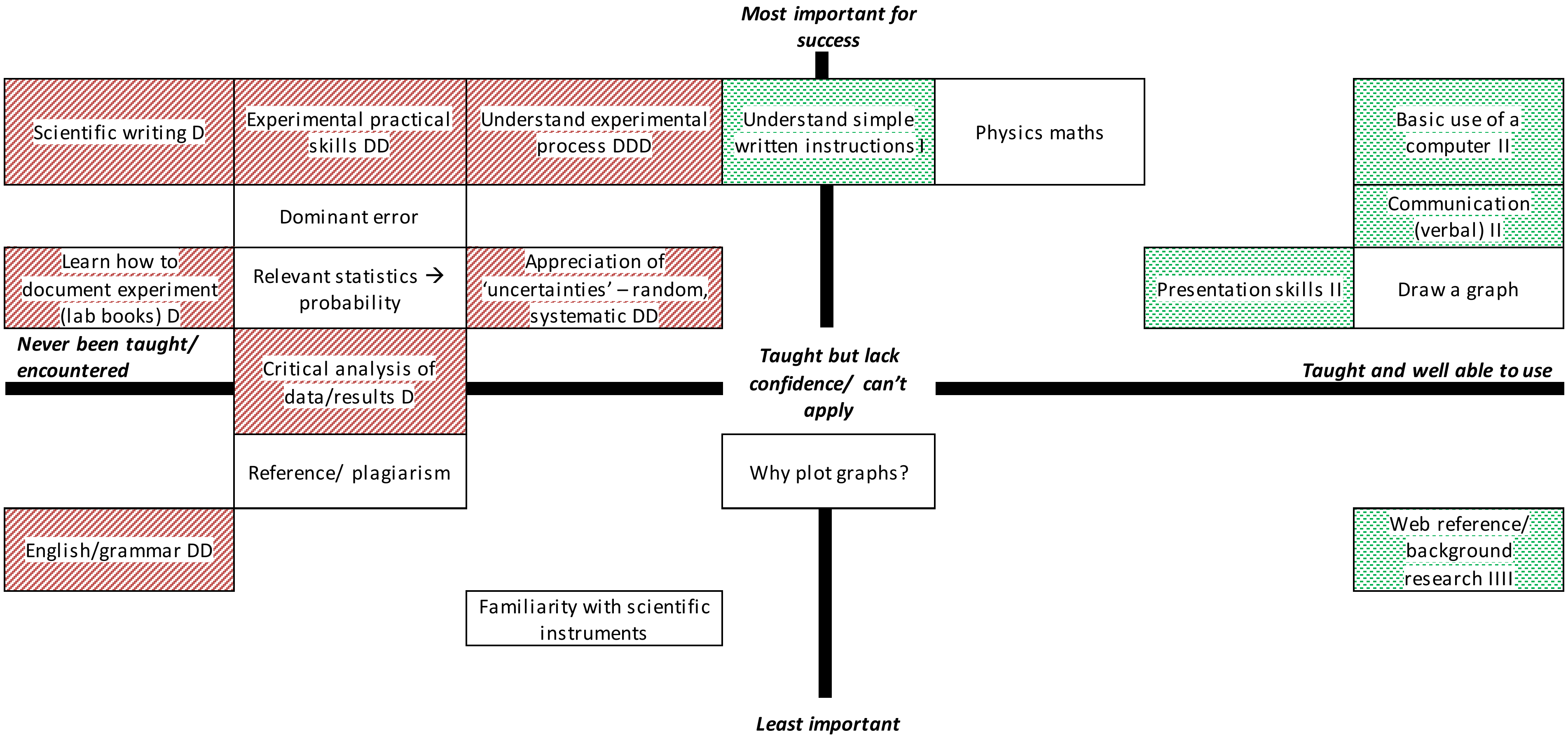
Physics group 1



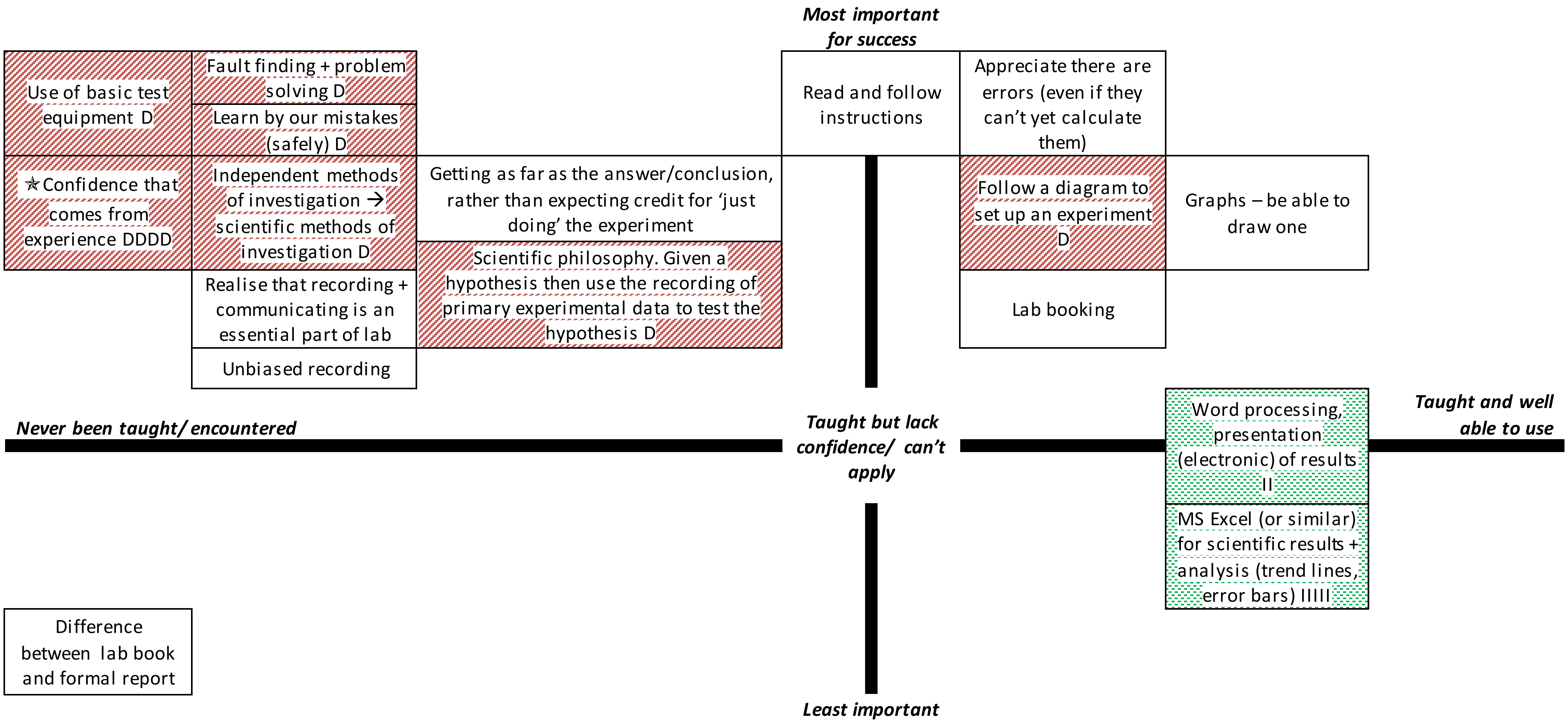
etc)

Least important

Physics group 2

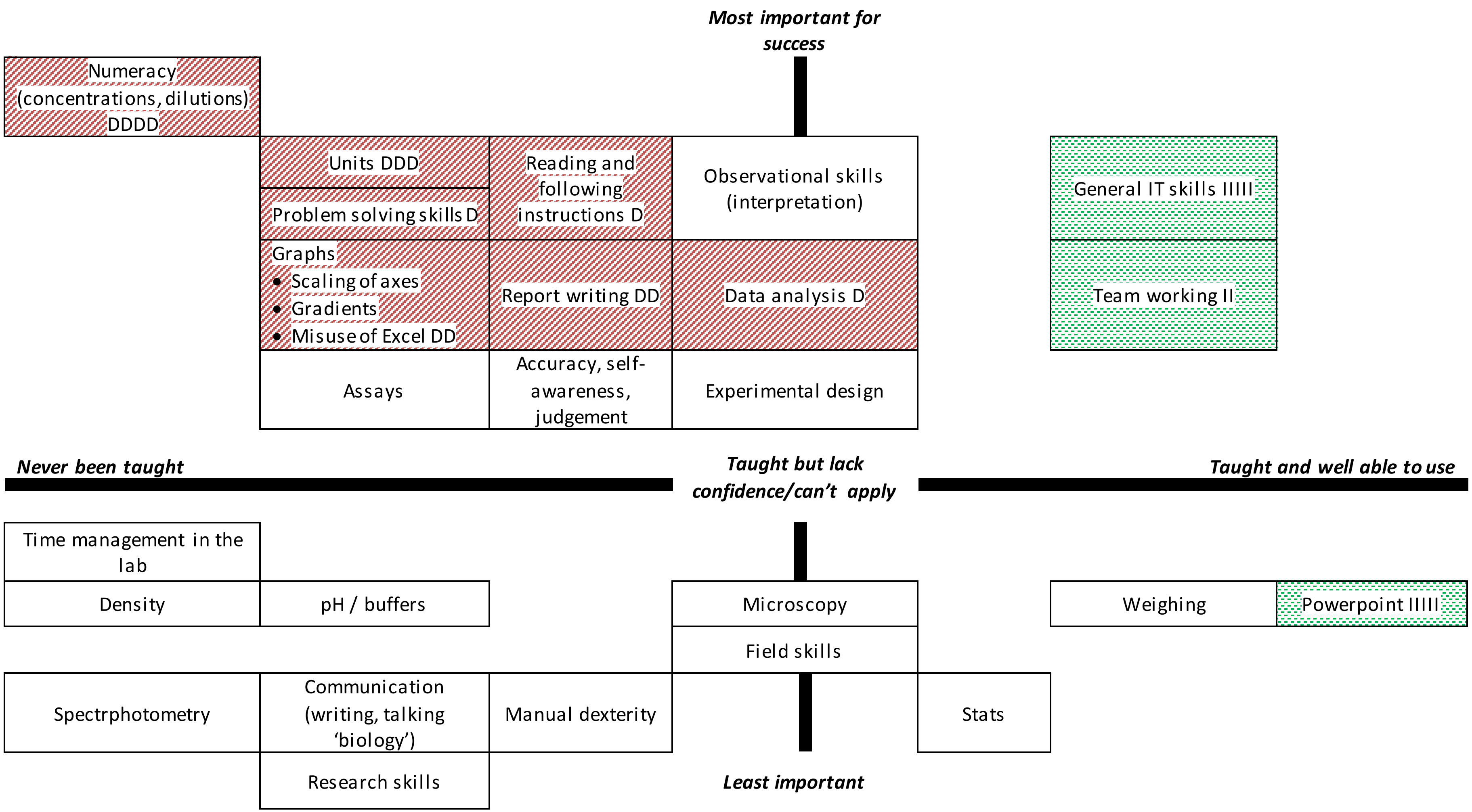


Physics group 3

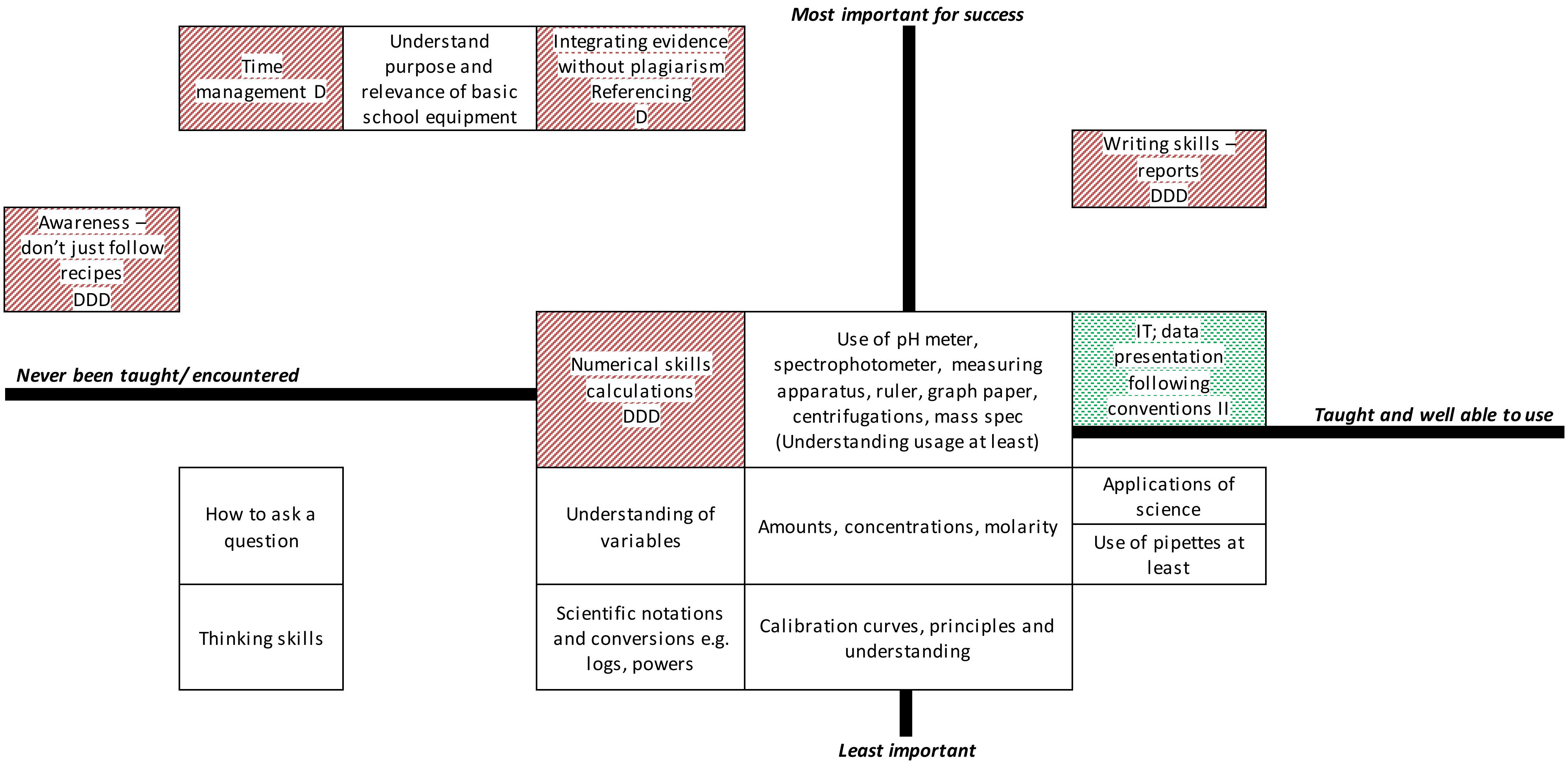


NB the star was drawn on to the post-it note for confidence because some group members wished to prioritise the idea of confidence. The arrow is a reproduction of how the group expressed the link between independent methods of investigation and scientific methods.

Biosciences group 1



Biosciences group 2



APPENDIX IV. Workshop facilitators' guide

Aim: To understand the practical skills that are required of various undergraduate science and related courses, whether there is s deficit in any skills areas and which areas are improving/declining. The ultimate aim of the work is to understand how science A levels (or equivalents) can better prepare young people for undergraduate courses in the sciences in terms of practical work.

Key questions:

- What practicals are undertaken in first year? Which are common across departments?
- What key skills/competencies do first years need to come equipped with to succeed? Do these differ (and if so how) between subjects, types of universities and students from different countries within the UK and beyond?
- How do undergraduate teachers define 'practical skills'?
- Which of these skills are first years well equipped with, and which do they lack? Are certain skill levels improving or declining? To what extent is there consensus among undergraduate teachers about any trends?
- What are the most interesting/useful avenues to pursue in any further research on this topic?

Notes for facilitators:

- Can keep a broad definition of practical skills, but need to make sure that if it goes too far off track we bring them back to lab skills as we would frame them (i.e. excluding maths, problem solving etc if these are not related to the lab)
- There may be some very strong views on the subject, so need to maintain balance and constantly probe for alternate views, make sure we are not assuming there is a decline.
- Can prompt with some skills from the GCE list near the end of sessions, but priority is on those that they raise themselves

Pre-workshop task: find and bring a list of the experiments/activities you ask your first year undergraduate students to complete. Facilitators to collect these lists from each participant (ideally emailed through beforehand along with registration details).

Time		Task	Details
11.30	60	**Setup and briefing**	Facilitators meet at venue to check room setup and agree details. • Write agenda on flipchart • Prepare matrices on flipcharts • Check catering arrangements • Put up signs
12.30	30	**Registration and lunch**	Participants arrive, register and have lunch
13.00	30	**Introductions**	Introduction to the workshop (agenda) by LG • Welcome and thank host if applicable • Background to study – invite Gatsby to contribute this • Chatham House Rule • Emphasise that this is a research workshop – so we are asking you to capture lots of ideas. Run through agenda • Introduce me, Sarah, Gatsby observers Participant introductions and ice breaker (name, department, institution and your favourite experiment from your student days)
13.30	40	**First year activities**	Split groups into disciplines – two breakout focus groups. Based on the lists of experiments participants have brought with them, their goal is to identify which experiments/techniques are common across departments and which are unique. Start in pairs/threes and note unique and shared experiments/activities. • Each pair write down one experiment per post-it/page, and group as to whether they are unique to the institution, or shared. • Pairs encouraged to draw similar experiments together, e.g. using an oscilloscope, so seeking what they do in common rather than highlighting differences.

<table>
<tr><td></td><td></td><td></td><td>Pairs/threes join to fives and repeat, finally whole group comes together to create a list of shared activities, and a list of unique activities. Display lists in the room.</td></tr>
<tr><td>14.00</td><td>20</td><td>Required practical skills</td><td>In breakout groups still, participants think about the question (NB kept open on purpose):

What do new undergraduates need to succeed in these practicals?

A range of lab skills, transferable skills and other competencies (e.g. maths, confidence) may come up, which is fine
Participants write ideas on post-it notes, one idea per sheet, use sharpie pens so its easy for others to read
As a group, cluster the ideas if appropriate (might not cluster because of the importance scale) and remove duplicates
Prompt with skills identified in GCE specs if they don't come up spontaneously (only prompt near the end)
Invite Gatsby observers to ask questions</td></tr>
<tr><td>14.20</td><td>40</td><td>Which skills do undergraduates possess and which are improving / in decline</td><td>Then – intro matrix with importance of skill on vertical axis, and extent to which students are well-equipped on horizontal axis.

How well equipped are students to use these skills?

Facilitator identifies second dimension. Aim is that we now have two scales with the skills on: how important they are to UG teachers, and how well equipped students are with the various skills.
To what extent have first years:
never been taught the skill;
have been taught the skill but lack confidence in using it/ don't know understand how to use it in the context of the practical activity you have set them?
Have been taught the skill and are confident and well able to use it
Facilitator: make notes of points of discussion while the group work on this</td></tr>
</table>

			Probes: • Is this a problem? • Have students always been good/bad at this? If its changed, over what time period have the changes taken place? • Where do you get your evidence for these findings? How confident are you in this? • Invite Gatsby observers to ask questions
15.00	20	**Coffee break**	Participants use stickers to mark the skills which they feel have been in decline in the last 5-10 years, and (with a different colour sticker) which have improved. Participants have three green (improving) and three red (declining) stickers each to deploy as they see fit. Opportunity for the groups to inspect each others' lists of skills before the next session
15.15	45	**Wider discussion**	As two breakout groups, but mixed this time between the disciplines. Facilitator: make notes of points of discussion while the group work on this Facilitated discussions. Topic guide: • What are the differences between the two subjects that are represented here? • Are there any overall trends in the activities or skills we have discussed? • What might the reasons behind the trends be? • What support or training is provided for those that teach in the lab? • Is the picture different for different types of institution? What are the factors that make these different? • How are your institutions responding to this? • What haven't we covered in today's discussion that is important? • Invite questions from Gatsby observers
16.00	15	**Research questions**	As a group, come up with **three research questions that you would like to see explored further** (note – be careful to manage expectations at this point, there is no guarantee that the study will take place or that all suggested questions will be able to be included)
16.20	15	**Thanks and**	Thank and close, outline of next steps including reporting. Final word to Gatsby rep if they would like to.

		close	Feedback: what worked well and would be better if.