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How courses can be adapted to address skills' needs – learning from another STEM discipline

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Mike Edwards, with Natalie Capel,
Laura Hancock, Katherine Haxton, Martin Hollamby, Richard Jones, David McGarvey, Daniela Plana and Aleks Radu

School of Chemical and Physical Sciences

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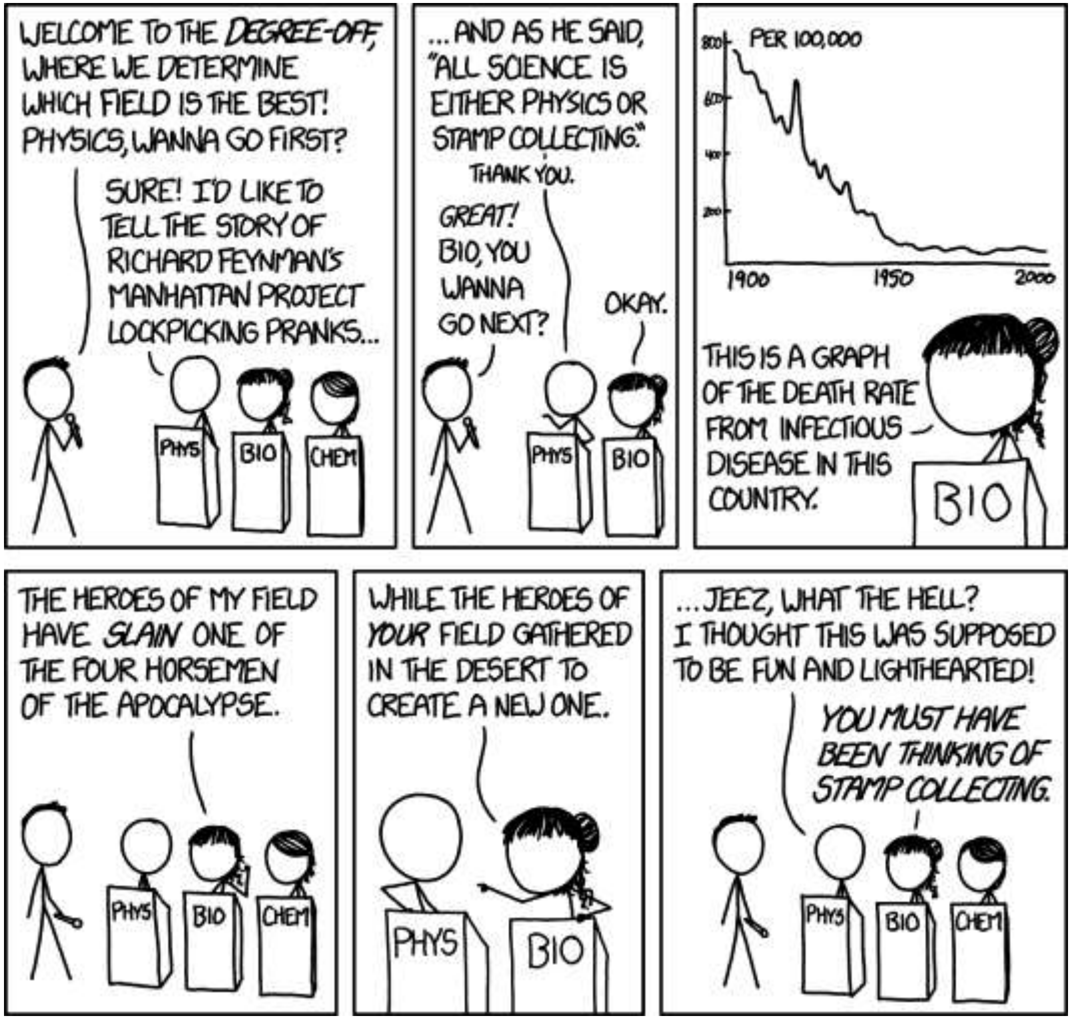
Perception – sciences and scientists are different…



https://xkcd.com/1520/

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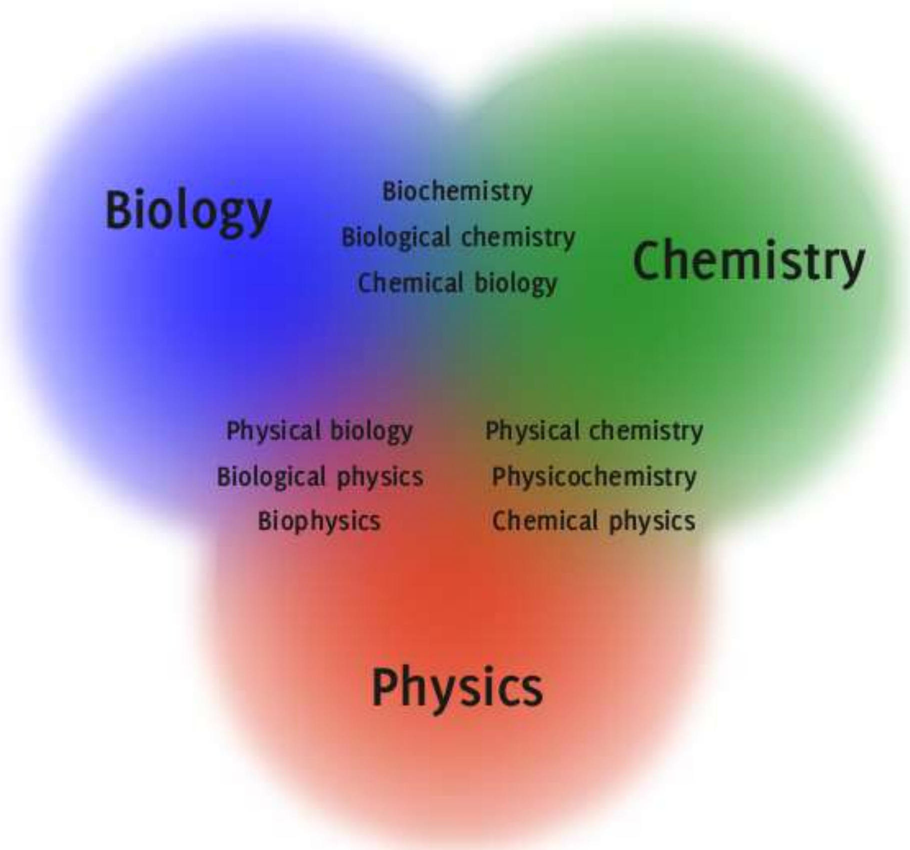
Core sciences – how different are they? Are the students different?



http://blogs.hightechhigh.org/sstaley/2013/08/27/question-about-physics/

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Subject Benchmark Statement: Chemistry

https://www.qaa.ac.uk/quality-code/subject-benchmark-statements

Professional skills

5.7 In bachelor's degree with honours programmes, students develop:

- communication skills, covering both written and oral communication with a variety of audiences
- skills in the employment of common conventions and standards in scientific writing, data presentation, and referencing literature
- problem-solving skills, relating to qualitative and quantitative information
- numeracy and mathematical skills, including handling data, algebra, functions, trigonometry, calculus, vectors and complex numbers, alongside error analysis, order-of-magnitude estimations, systematic use of scientific units and different types of data presentation
- information location and retrieval skills, in relation to primary and secondary information sources, and the ability to assess the quality of information accessed
- information technology skills which support the location, management, processing, analysis and presentation of scientific information
- basic interpersonal skills, relating to the ability to interact with other people and to engage in teamworking
- time management and organisational skills, as evidenced by the ability to plan and implement efficient and effective ways of working
- skills needed to undertake appropriate further training of a professional nature
- other relevant professional skills such as business awareness.

Subject Benchmark Statement: Physics

https://www.qaa.ac.uk/quality-code/subject-benchmark-statements

3.11 Generic skills include:

i problem-solving skills - physics degree courses require students to solve problems with well-defined solutions. They also allow students to gain experience in tackling open-ended problems that may cross subject boundaries. Courses allow students to demonstrate their ability to formulate problems in precise terms and to identify key issues. They enable students to develop the confidence and creativity to try different approaches in order to make progress on challenging problems

ii investigative skills - physics degrees provide students with the opportunity to develop their skills of independent investigation. Students gain experience of using textbooks, and other available literature, of searching databases and the internet, and of interacting with colleagues to derive important information

iii communication skills - physics, and the mathematics used in physics, deal with surprising ideas and difficult concepts; good communication is essential. Physics degrees allow students to demonstrate their ability to listen carefully, to read demanding texts, and to present complex information in a clear and concise manner to a range of different audiences

iv analytical skills - physics degrees help students learn the need to pay attention to detail and to demonstrate their ability to manipulate precise and intricate ideas, to construct logical arguments and to use technical language correctly

v ICT skills - physics degrees provide the opportunity for students to acquire these skills in a variety of ways

vi personal skills - physics degrees allow students to demonstrate their ability to work both independently and in a group. Independently they are able to use their initiative, be organised and meet deadlines. In a group they are able to interact constructively as part of a team.

Degree accreditation Criteria

ROYAL SOCIETY OF CHEMISTRY

Quality assurance

KR14: Universities must have robust quality assurance mechanisms in place for all aspects of its programmes.	Applicable to: **all programmes**

- A clear quality assurance framework should be in place and actively applied to ensure that outcome standards are appropriate, consistent and fair.
- QA processes must assure that:
  - programmes are adequately supported by learning resources
  - agreed specifications are followed
  - assessments are set at the appropriate standard
  - assessment processes are impartial and robust
  - successful students achieve the stated learning outcomes and are graded accordingly
  - students can progress fairly and effectively
  - content and assessments are regularly reviewed
  - feedback is obtained and considered from students
  - future stakeholder/employer input is sought on a regular basis through forums such as industrial advisory boards

https://www.rsc.org/globalassets/03-membership-community/degree-accreditation/accreditation-of-degree-booklet.pdf

Industrial Input is Crucial

Focused input from an industrial liaison panel can identify skills requirements – research collaborators are an excellent resource pool:

- ✓ Limited reporting skills
- ✓ Limited understanding of career requirements and skills
- ✓ Limited understanding of chemical industry

Industrial reports provide useful 'big-picture' skills requirements to aid course design

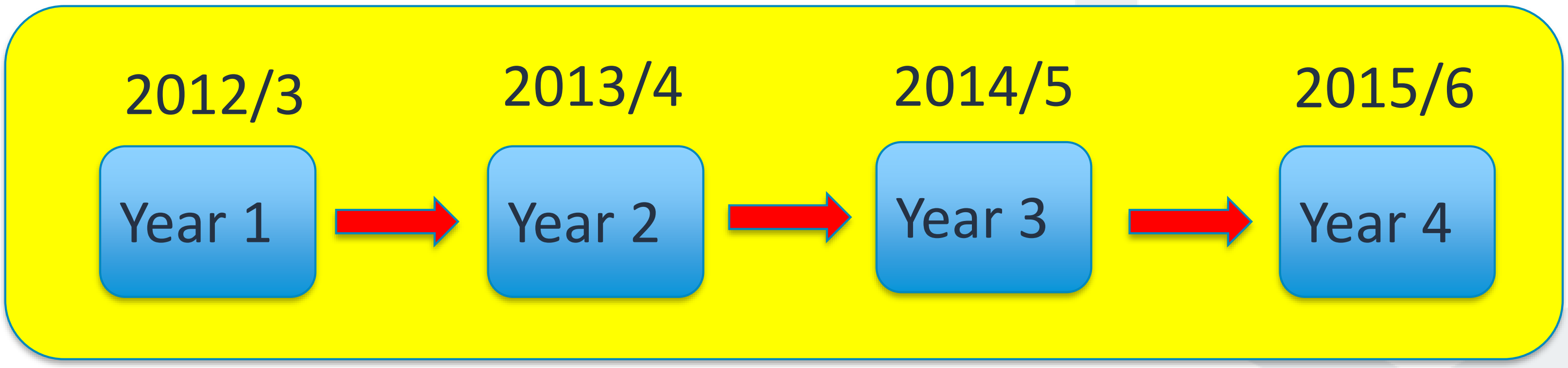
https://www.abpi.org.uk/publications/bridging-the-skills-gap-in-the-biopharmaceutical-industry-2019/

Desirable Skills Outcomes

- ✓ **Scientific numeracy** – *understanding the meaning of numbers and their manipulation and application in a scientific context*
- ✓ **Scientific literacy** – *the ability to locate key information from books, journals and databases and distil their important elements*
- ✓ **Scientific communication** – *the ability to summarise, report and communicate experimental findings through a variety of media*
- ✓ **Professional skills** – *the ability to professionally carry out and obtain data using a range of discipline specific techniques*
- ✓ **Employability skills** – *the ability to solve problems, working individually or as part of a team, using the range of skills developed*

Course Design – what is important?

Chemistry at Keele embarked on a rolling programme level redesign commencing in 2012/13:



- ✓ Focused on the identified programme level outcomes
- ✓ Providing structured opportunity to develop from feedback
- ✓ Teaching key objectives through embedding them in assessment

Case Study 1: Building Report Writing Skills

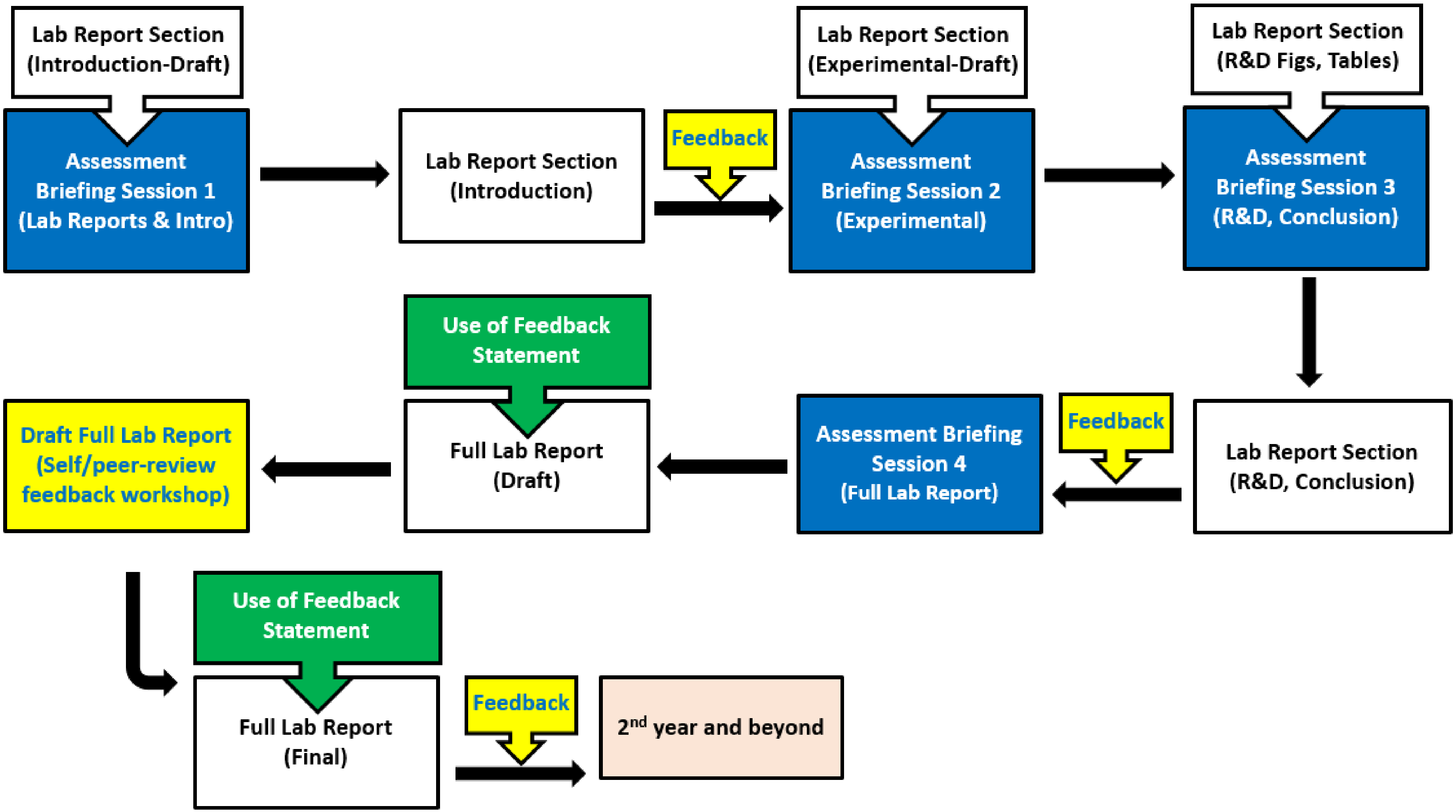
- ✓ Report writing skills are a ubiquitous (and traditional) component of undergraduate science degree courses and generally act as a vehicle for reporting the outcomes of laboratory experiments/investigations through ***laboratory reports***.

- ✓ '***Laboratory report***' encompasses a variety of styles/formats, ranging from prescriptive *pro-forma* style reports to '*full write-ups*'.

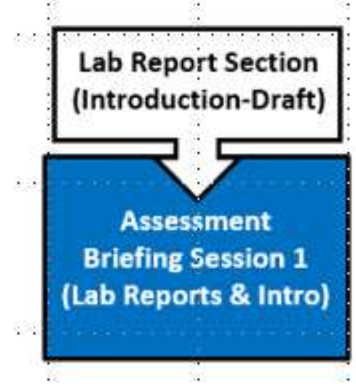
- ✓ These may be hand-written or word-processed, and highly variable in expectations of the generic skills students are required to practice and demonstrate.

Iterative Dialogic Assessment and Feedback Cycles

1. Students write laboratory report sections mirroring the principal sections (Introduction, Experimental, Results and Discussion, Conclusion) of chemistry journal articles
2. Students draw on their feedback from the sections to compile a draft full article/report.
3. Students improve their drafts and submit their final lab reports.

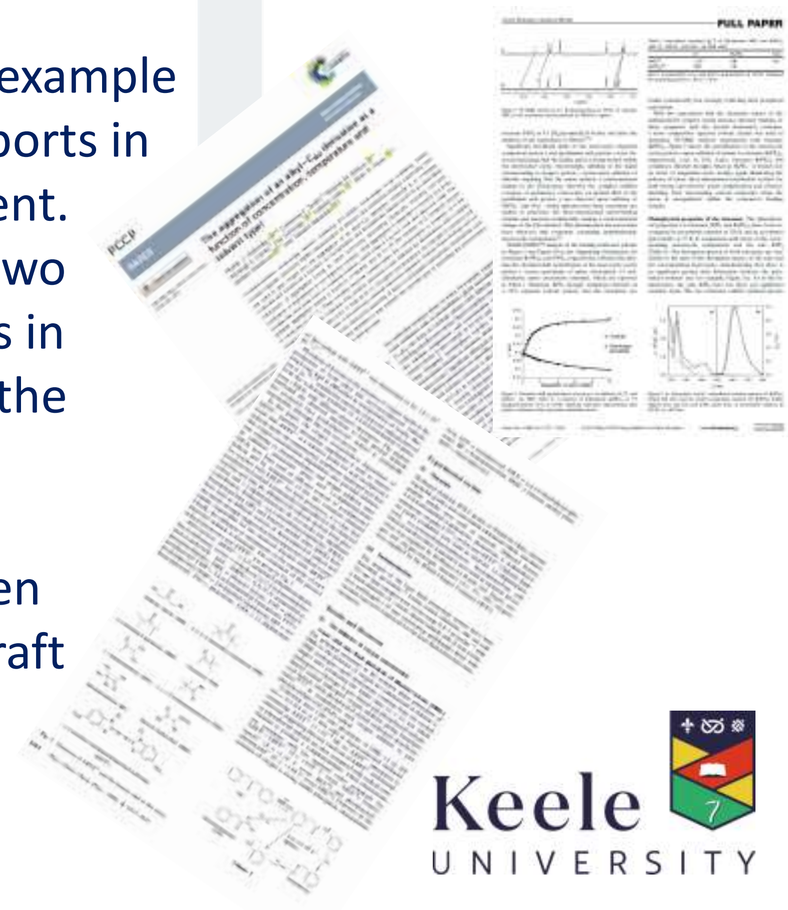


Assessment Briefing Session 1 (2hrs)



- ✓ **Exercise 1:** Students, working in groups, survey a selection of journal articles to identify common features, principal sections, conventions and practice (followed by discussion).

- ✓ **Exercise 2:** Students are provided with two example reports: They compare and contrast the reports in terms of strengths and areas for improvement. Using the marking criteria, they assess the two reports and write some feedback comments in relation to the different aspects defined by the marking scheme.



- ✓ **Exercise 3:** Students reflect on what has been discussed during the session and on their draft introductions, they write action points for improvements to make.

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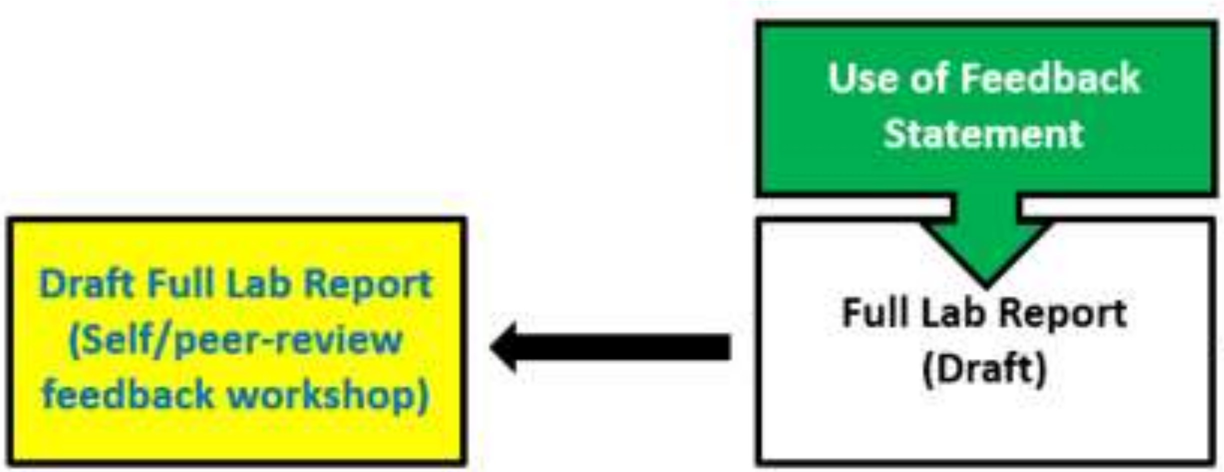
Draft Full Laboratory Report Feedback Workshop (2 hrs)

1. Tutor-facilitated group discussion/review of sets of anonymised peer draft lab reports.
2. Self-assessment of student's own work against the marking criteria.
3. Summary feedback and Q&A session.



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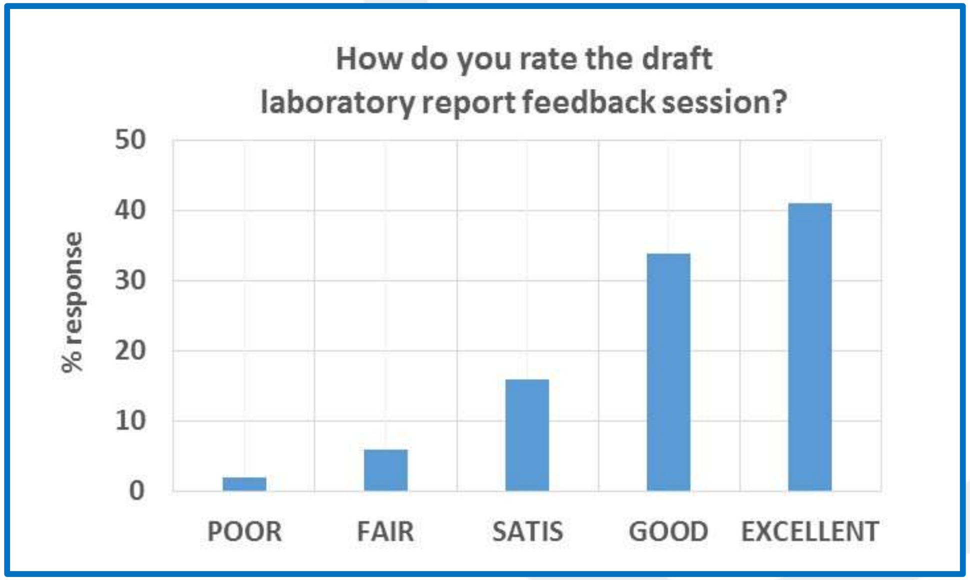
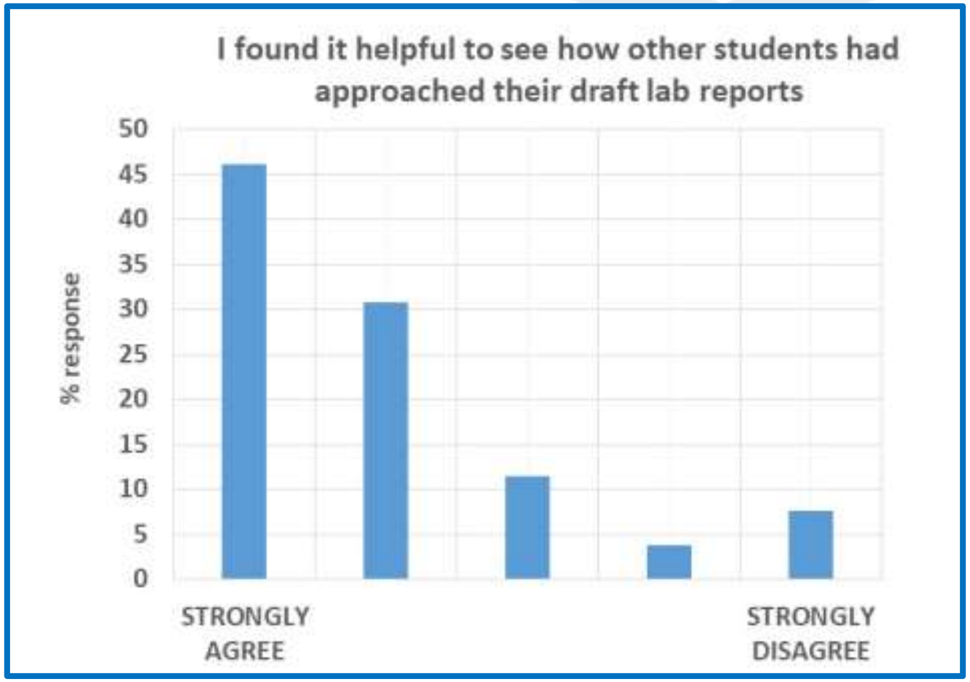
Feedback Workshop: Student & Observer Feedback

- *'I was able to see what standard I should write my papers'*
- *'Helped me improve my lab report, found the session very useful'*
- *'Peer reviewing other lab reports was much more helpful than I thought it would be'*
- *'Looking at other people's reports and seeing how my own could be improved'*
- *'Got good feedback on my draft and had an opportunity to see other people's reports'*
- *'I was expecting to get more feedback from the lecturers*



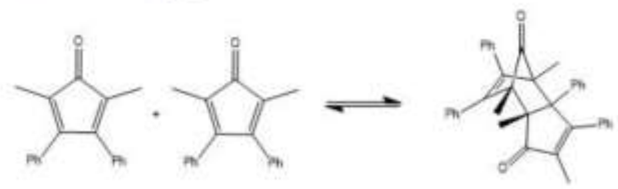


IMPACT? WHAT STUDENTS CAN DO

Temperature Dependence of Equilibrium Constants and the van't Hoff equation

Introduction

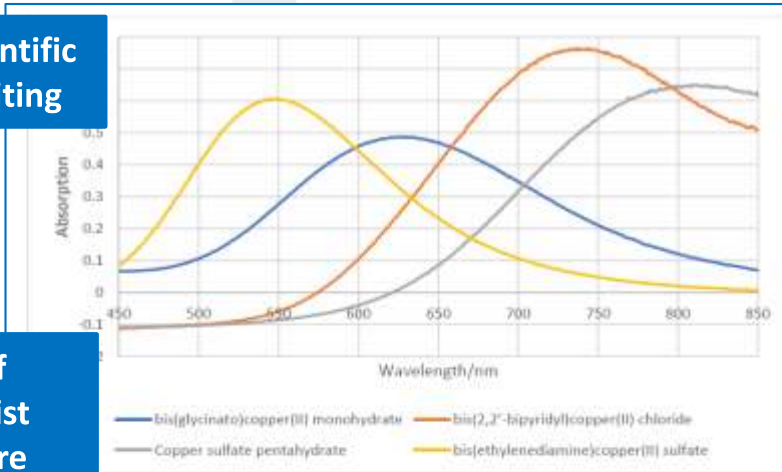
The compound 2,5-dimethyl-3,4-diphenyl cyclopentadienone can undergo a reversible dimerization reaction in solution via a Diels-Alder reaction. 2,5-dimethyl-3,4-diphenyl cyclopentadienone exists as a dimer (as seen in Scheme 1) as a solid. However, when this dimer - 'D' - is dissolved in an organic solvent it can, to an extent, spontaneously dissociate into a monomer - 'M' - (as seen in Scheme 1). This dissociation is temperature dependent. As soon as the monomer is formed, an equilibrium will begin to be established and the monomer will react and turn back into the dimer. Once this equilibrium has been determined both the forwards and backwards reactions will progress at the same rate.



(1) - Monomer (1) - Monomer (2) - Dimer

Scheme 1. Reaction of a reversible dimerization of 2,5-dimethyl-3,4-diphenyl cyclopentadienone[1]

Scientific writing



Use of Specialist Software

Figure 8. UV-Visible spectrum of the copper complexes

[1]**H NMR Data:** Equation 4 was used to calculate the dissociation of the dimer (α) from the ratio of protons in each environment (R). Equation 3 was then used to calculate the value of K for the solution at each temperature.

Professional Conventions

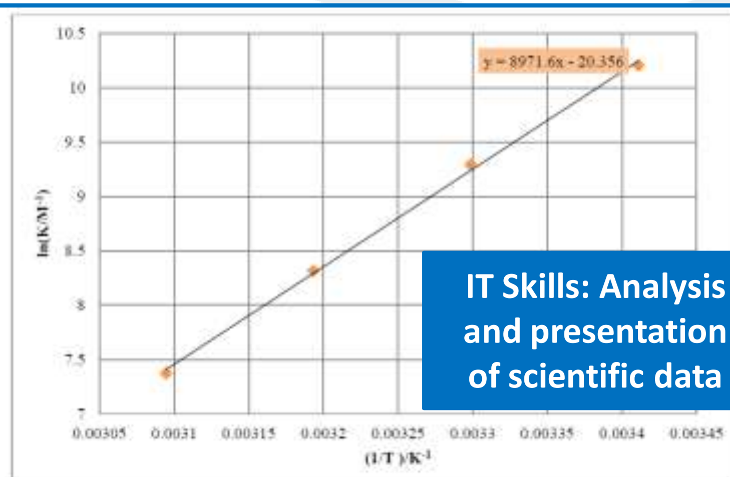
$$\alpha = \frac{R}{(2+R)} \qquad (4)$$

$$K = \frac{(1-\alpha)}{4[D]_0\alpha^2} \qquad (5)$$

Values obtained experimentally were compared to those from the solution analysed by ^{1}H NMR spectroscopy. Figure 2, a ^{1}H NMR spectrum of the solution at 298K shows five integrated peaks, four of which are from the dimer and one of which is the monomer. This shows the presence of both the reactant and product at equilibrium at the start.

T/K	(1/T)/10^{-3} K^{-1}	[M]$_e$/10^{-3} mol L^{-1}	R/10^{-2}	α/10^{-2}	K/10^{3}M^{-1}	ln(K/M^{-1})
293	3.411	0.679	5.446	2.651	27.063	10.206
303	3.299	1.063	8.661	4.151	10.866	9.293
313	3.193	1.711	14.321	6.682	4.082	8.314
323	3.095	2.682	23.413	10.480	1.592	7.373

Table 1.3- Shows the values calculated using equations 4 and 5 from ^{1}H NMR spectra



IT Skills: Analysis and presentation of scientific data

Figure 3.1- shows the van't hoff plot of the solution analysed by ^{1}H NMR spectroscopy

References

1. CHE-10049 Practical and Professional Chemistry Skills II, Laboratory Manual, School of Chemical and Physical Sciences, Keele University, 2016-17.
2. A A Gordus, *J. Chem. Educ.* 68, (1991), 138
3. H M Weiss, *J. Chem. Soc., Perkin Trans.* 2, (1991), 429-443
4. B Fuchs and M Pasternak, *J. Chem. Soc.,Chem Comm* (1977), 537-538

Referencing

23 Developing scientific reporting skills of early undergraduate chemistry students

Natalie J. Capel, Laura M. Hancock, Katherine J. Haxton, Martin J. Hollamby, Richard H. Jones, Daniela Plana and David J. McGarvey
School of Chemical and Physical Sciences, Keele University
d.j.mcgarvey@keele.ac.uk

The approach is characterised by a series of iterative assessment-feedback cycles that are supported by scheduled assessment briefing sessions coupled to a range of formative and collaborative learning activities related to aspects of report writing

Capel, N. J., Hancock, L. M., Haxton, K. J., Hollamby, M. J., Jones, R. H., Plana, D. and McGarvey, D. J. (2019), "Developing scientific reporting skills of early undergraduate chemistry students", in Seery, M. K. and Mc Donnell, C. (Eds.), Teaching Chemistry in Higher Education: A Festschrift in Honour of Professor Tina Overton, Creathach Press, Dublin, pp. 333-348.

Case Study 2: Assessing Employability Skills

Second year students submit a CV and cover letter in response to an internship advert – careers exercise embedded in a core module

- ✓ Collaboration with the careers service
- ✓ Feedback and guidance
- ✓ Aligned to the subject material
- ✓ Low-stakes assessment

Case Study 2: Assessment Pathway

Advert and ‘bad’ CV discussed

Individual submissions

Careers service cohort follow up

Assessment briefing → Formative CV draft → Expert feedback

↓

1 to 1 feedback ← Mark awarded ← Summative submission

Optional careers interview

No written feedback

Students revise submissions

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Case Study 2: Assessing Employability Skills

Assessment marks are determined by a simple set of criteria and the mark (out of 5) reflects suitability for the position:

5 - Call for interview, place on shortlist

4 - Consider for interview, add to long list

3 - Thank you for your application, we will keep your CV on file

2 - Thank you for your application

1 - No response

- ✓ Individual feedback is offered in 15 minute careers interviews
- ✓ Opportunity to review the CV and internship opportunities

Case Study 2: Outcomes

No (sharable) data on the success of this intervention but we have empirically observed:

- ✓ Enhanced links with careers resources and facilities
- ✓ Better career awareness amongst students
- ✓ Students obtaining summer internships/experience
- ✓ Some students will not engage

Conclusions and Thanks

- ✓ Science curricula can be modified and redesigned to reflect the outcomes we desire in our graduates using strategic assessment
- ✓ Industrial opinion and feedback is an important element of designing courses that are relevant for modern graduates
- ✓ Science disciplines can share ideas and good practice to the benefit of all
- ✓ Please email me if you would like to discuss anything further (m.g.edwards@keele.ac.uk)