Mini-projects: CURE-like lab projects to increase student learning

ViCEPHEC21
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Chemistry Lab Course at Birmingham

- 150 students in Years 1 and 2
- Roughly 70 in Year 3
- Timetable allows for an average one day per week per student in the lab
- Year 1 – a day at a time
- Year 2 – 2 days every fortnight
- Year 3 – a whole week at a time

- In 2018/19 moved into CTL (CTL Website)
- Led to major redesign of our lab course
New Lab Course focussed on development of practical skills into research skills (Seery, 2019)

Year 1
- Developing experimental skills, competence and laboratory procedures
  - Well-defined protocol experiments and unassessed skills sessions

Year 2
- Advanced experimental skills, experimental design (familiar)
  - Mix of defined experiments and developing approaches to test hypotheses

Year 3
- Experimental design (unfamiliar), scientific research
  - Designing and implementing experimental protocols on an unfamiliar topic
- Non-chemistry graduate careers
- Masters projects
- Chemistry graduate careers
- Research Skills

Practical Skills
What is a CURE? Dolan (2016) summarises some of the suggestions made in papers about what constitutes a CURE. N.B. there is no consensus!

- Discovery – novel results
- Relevance – of interest to external stakeholders
- Students’ engagement in scientific practices including:
  - reading scientific literature
  - designing some aspect of the project
  - engaging in collaboration
  - analyzing data
  - making interpretations
  - framing work in the larger body of knowledge
  - communicating results

Advantages of CUREs:

1. **Cognitive gains** such as increased content knowledge, improved understanding of the nature of science, or skill development, including analytical, technical, collaboration, communication, and experimental design skills;
2. **Psychosocial gains** such as increased confidence, self-efficacy, project ownership, sense of community, and scientific identity, as well as more frequent and fruitful interactions with faculty;
3. **Behavioral gains** such as staying in a science major, pursuing additional research opportunities, or enrolling in graduate school; and
4. **Affective and other “non-cognitive” gains** such as enjoying science class more and being more motivated
5. Allows access to research for students from **more diverse backgrounds** (Eagan, 2013)
Course-based undergraduate research experiences (CUREs)

Some background reading on CUREs:

*Course-based Undergraduate Research Experiences: Current knowledge and future directions* – Dolan (2016)
- good summary of CUREs in chemistry and life sciences, contains examples of CUREs from variety of institutions
- [https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_177288.pdf](https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_177288.pdf)

*Assessment of Course-Based Undergraduate Research Experiences: A Meeting Report* – Auchincloss (2014)
- Summary of a meeting of CUREnet (a network of biology academics interested in CUREs) discussing logistics and assessment of CUREs

*The Laboratory Course Assessment Survey: A Tool to Measure Three Dimensions of Research-Course Design* – Corwin (2015)
- Describes in-depth development of Laboratory Course Assessment Survey (LCAS) for monitoring students interaction with CUREs

*Characteristics of Excellence in Undergraduate Research* – edited by Hensel (2012)
- Collection of essays on undergraduate research
- [https://www.cur.org/assets/1/23/COEUR_final.pdf](https://www.cur.org/assets/1/23/COEUR_final.pdf)
### Mini-projects: Logistics for students

#### Activity

<table>
<thead>
<tr>
<th>Semester 1</th>
<th>Assessment</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 3 – Research workshop</td>
<td>Poster + Supervisor Mark</td>
<td>50% of module</td>
</tr>
<tr>
<td>Week 5 – One-week mini-project</td>
<td>Chem Commun paper 1 + Supervisor Mark</td>
<td>50% of module</td>
</tr>
<tr>
<td>Week 8 – Writing workshop 1</td>
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<td></td>
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<tr>
<td>Week 9 – One-week mini-project</td>
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<table>
<thead>
<tr>
<th>Semester 2</th>
<th>Assessment</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Week 7 – Two-week mini-project (1st week)</td>
<td>Chem Commun paper 2 + Supervisor Mark</td>
<td>100% of module</td>
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<tr>
<td>Week 8 – Writing workshop 2</td>
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<td></td>
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<tr>
<td>Week 9 – Two-week mini-project (2nd week)</td>
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- Students also meet with supervisors in weeks before and after the mini-project weeks to plan and debrief
- Workshops help explain the assessment to the students
- Broken into three mini-project to allow for feedback to improve future performance
Aim: Can bench-top NMRs be used to determine critical micelle concentrations?

- Usually measured using techniques such as conductivity or UV
- Can NMR prove as useful - potentially even more so?

NMR gives good approximation to the CMC for two surfactants

<table>
<thead>
<tr>
<th>Physical parameter</th>
<th>CPC CMC (mM)</th>
<th>DPC CMC (mM)</th>
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</thead>
<tbody>
<tr>
<td>T₁ relaxation</td>
<td>0.65</td>
<td>14.22</td>
</tr>
<tr>
<td>T₂ relaxation</td>
<td>0.72</td>
<td>16.27</td>
</tr>
<tr>
<td>UV (EE)</td>
<td>1.02</td>
<td>13.26</td>
</tr>
<tr>
<td>UV (Fluorescein)</td>
<td>-</td>
<td>10.36</td>
</tr>
<tr>
<td>Conductivity</td>
<td>1.02</td>
<td>18.66</td>
</tr>
<tr>
<td>Conductivity (EE)</td>
<td>1.20</td>
<td>17.05</td>
</tr>
<tr>
<td>Literature values</td>
<td>0.90²</td>
<td>14.9³</td>
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NMR identified a phase change in the micelles not picked up by traditional methods
Exemplar Mini-projects: Upcycling Plastic Waste

Aim: Can we improve the efficiency of plastic recycling?

- Building on Prof Andrew Dove’s work on recycling plastics
- Students are given free reign to explore the area based on their own ideas

Group 1 – optimisation of catalytic regime for depolymerisation

Figure 3: Graph of Conversion vs Time for 5-minute reaction monitoring

Group 2 – Can BPA-PC be recycled selectively in presence of PET

Scheme 3: Depolymerisation of BPA-PC and PET with a nucleophile where $R = \text{O/NH}$. Schemes carried out with aliphatic nucleophiles yielding a heterocycle and (aromatic) nucleophiles yielding a (diphenol derivative). Monomers include a BPA and a BHET derivative (see table 4)

Table 3 BPA and BHET derivative yields from BPA-PC depolymerisation reactions

<table>
<thead>
<tr>
<th>Entry</th>
<th>Nucleophile</th>
<th>T (°C)</th>
<th>Time (h)</th>
<th>BPA yield (%)</th>
<th>BHET derivative (%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1A</td>
<td>190</td>
<td>24</td>
<td>73</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td>190</td>
<td>24</td>
<td>76</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>3A</td>
<td>190</td>
<td>24</td>
<td>52</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4A</td>
<td>190</td>
<td>24</td>
<td>22</td>
<td>13</td>
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* Yields calculated from 1H NMR using TBD:MSA as an internal standard
Over the course of the mini-projects, students’ understanding of the skills required for research increased.
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Their confidence also increased – importantly not linked to the mini-projects seeming easier.
Mini-projects: Student Feedback

Student survey shows the students enjoyed their mini-projects and found it increased their interest in science and the subject area of their mini-project.

Also highlights the students learnt about the process of scientific research.

Sample of student quotes:

“The last two years of labs makes sense now”

“I didn’t know that this is what physical chemistry was, I understand why people like it now”

“I now know what subject I want to research now” – student went on to do Masters in Polymer chemistry in Europe
### References & Acknowledgements


### Development Support

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<thead>
<tr>
<th>Academic supervisors</th>
<th>CTL Staff</th>
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<tr>
<td>Prof Rachel O’Reilly – Head of School</td>
<td>Dr Cheryl Powell – Wet Lab Manager</td>
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<tr>
<td>Dr John Snaith – Head of Education</td>
<td>Dr Charles Manville – Wet Lab Technician</td>
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<tr>
<td>Dr Robert Laverick – Teaching Fellow</td>
<td>Dr Leticia Millward – Wet Lab Technician</td>
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### Academic supervisors

- Prof Tim Albrecht – Monitoring Enzyme Kinetics
- Dr Phoebe Allan – Optimising Battery Composition
- Dr Tamas Bansagi – Enzyme Nanoreactors
- Dr Melanie Britton – Determination of CMC
- Dr Dwaipayan Chakrabati – Global Optimisation
- Dr Liam Cox – Drugs against Neglected Diseases initiative
- Dr Paul Davies – Optimisation of an Organocatalytic Aldol
- Prof Andrew Dove – Upcycling of Plastic Waste
- Dr Sarah Horswell – Langmuir Troughs
- Dr Amanda Pearce – Antimicrobial Polymers
- Prof Zoe Pikramenou – Analysis of Lanthanide Complexes
- Dr Zoe Schnepp – Developing Outreach Activities
- Dr Ian Shannon – Macrocyclic Synthesis
- Dr John Snaith – Determination of Reaction Mechanism
- Prof Peter Slater – Synthesis and Analysis of Apatite Pigments
- Prof Jim Tucker – Dopamine Sensing
- Dr Adrian Wright – Main Group Catalysis for Sequestering CO₂