The Capstone Experience

Since 2001 I've been the final-year research project module leader (200 students) in a School of Biomedical Sciences at a research-intensive University.

The Biosciences QAA Benchmark Statement requires students to undertake a final-year research-based assignment[1]. For the vast majority of UK Bioscience students, this comprises of laboratory-based, fieldwork or literature projects. However I discovered that less than 10% of my students were going onto careers in research, with the majority leaving science altogether[2]. This led me to question if traditional research projects, with their focus on gaining research experience, equipped the majority of my graduates with the necessary skills and attributes to be "*workplace ready*"[3]. **Radical change was required** – involving a total rethink of the purpose, practices and outcomes of undergraduate research projects in order to **better prepare my students** for an increasing challenging **21st Century workplace**.

Development of Capstones:

My educational philosophy is to give students ownership of their learning, to provide them with inspirational, inclusive high-impact educational opportunities which promote their personal and professional development[4]. Final year projects are an ideal vehicle to achieve this.

As a highly experienced science communicator, in 2004 I was going into schools regularly to debate animal experimentation. Recognising this would make an ideal alternative project, I collaborated with one student to co-deliver an ethics-focused workshop at the 2005 Leeds Festival of Science[5]. Following on from the success of this workshop, we ran subsequent ones in Schools.

These projects were not hypothesis-driven research projects. Instead, they provided engaging educational activities for pupils. They also inspired my students who facilitated the events, and massively contributed to their personal and professional development. They provided both a service-learning[6] and capstone experience[4]. Feedback from students was excellent:

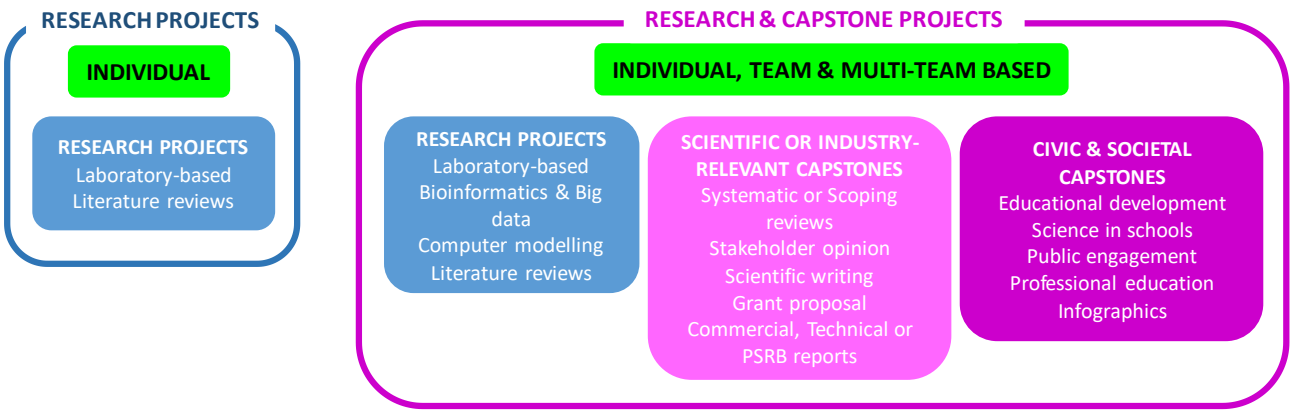
"So rewarding, the highlight of my four years in Medicine, indeed my whole education. I gained so much from it personally and professionally"
(Intercalating Medic)

All capstones require students to take knowledge and understanding from earlier years of their programme and apply it to a problem, creating a solution to that problem. A high impact educational practice, their principal purpose is personal and professional development[4,7], matching exactly with my educational philosophy.

I decided to break the traditional Biosciences research project mould[9] and create an innovative portfolio of **inclusive capstone opportunities** for my students which enabled each and every one to realise their full academic potential and personal goals. Any activity that develops skills and provides work experience can be a capstone.[8,9]

Since 2005, I've progressively created a **sector-leading portfolio** of ten **capstone opportunities**, a combination of both scientific/industry-relevant capstones, and those with a civic/societal focus (Figure 1). Capstones are offered alongside an expanded range of traditional research projects.

A



B

	2005	2012	2021
Capstone students	1	22 (13%)	46 (27%)
Research project students	211	153 (87%)	128 (73%)
Capstone supervisors	1	9 (21%)	18 (44%)
External partners	1	7	18

Figure 1: Progressive development of research and capstone project opportunities. A: Formats of research or capstones available in 2003-04 & 2020-21. B: Numbers of research project and capstone students, colleagues supervising capstones and external partners. Student % = % of students enrolled. Supervisors % = % of total supervisors on module

High-impact Educational Partnerships:

I realised that **inclusive partnerships**[10], where everybody (student, educator, external partner) could contribute and are equally valued and respected was critical, embedding multiple forms of partnership and high-impact educational practices throughout:

- Mentors (educators) guide and support their mentees (students) as they undertake their capstone. Mentors give mentees ownership, allow them to make mistakes, reflect on these and learn from them (**reflective learning**[11]).
- Mentees allocated to the same capstone work collaboratively, as a team, to achieve its outcomes. They develop as a **learning community**[10], mentoring and supporting each other;

"Instead of becoming stressed and demoralised, we worked through the problem optimistically as a team; using our initiative, defining what the problem was, what our options to move forward were and seeking help where appropriate"
(Physiology student)

- Mentees collaborate with their mentor to co-create new formats of capstone. The first two years of a new format is developmental, partners working collaboratively not only to achieve the capstone outcomes, but also to develop the format and guidance. These "*how to do it*" guides[12,13] are shared to support others (**students as partners**[10]);

- Established mentors **mentor** new academic **colleagues**, supporting them, in what for many is outside their comfort zone;
- I develop **partnerships** with **external organisations**, identifying their organisations needs for specific outputs which they don't have the resource to deliver (Patient information leaflets for GPs), creating capstones which deliver these.

Inclusion:

Inclusive learning partnerships where everybody can contribute their individual ideas, expertise and skills, and all are **equally valued** and **respected** are bedrock of my capstones. Students are not supervised by educators. Instead, educators are mentors, and student's their mentees. Mentees choose the capstone that addresses their specific developmental needs.

By offering a broad portfolio of capstones, each developing different skills and attributes, there is something for every student, an opportunity to excel irrespective of background. My students seize this opportunity, visibly growing in confidence as their capstone progresses. I encourage them to regularly reflect on their experiences, to demonstrate to themselves the **transformative impact** of their capstone.

By choosing a real-world assessment tool which best showcases their knowledge, skills, understanding, students can **showcase themselves to educators** and **employers**.

They become role-models, in turn inspiring others from disadvantaged backgrounds[14].

Mentees:

Student voice is very important to me. By offering a broad portfolio of opportunities, students can decide what they individually want to get out of their capstone, and choose accordingly. They love them. It open their eyes to new career opportunities:

"Always loved working with children, but this project has allowed me to realise it may be my "calling"
(Neuroscience student)

Developing key skills and enhancing their employability for careers outside of research:

"Excellent opportunity to demonstrate your aptitude in a scientific, non-laboratory working environment"
(Medical Sciences student)

They have wholeheartedly grasped this opportunity, excelling academically. Their module marks are significantly higher than students undertaking traditional research projects (2020: mean ± SD = 71.4±4.4% vs 68.4±5.8%, $p>0.05$, capstone vs traditional).

Students are voting with their feet! In 2020-21, 26% selected capstones as their first choice of project. A massive cultural shift given laboratory projects have traditionally been viewed as the "gold-standard".

Mentors:

I have successfully influenced academic colleagues in a very research focussed discipline and Institution to recognise the academic rigour and high-quality outputs of capstones:

"Demanding for students and supervisor. The standard of work produced is a credit to all concerned"

(Professor)

In 2020-21, 44% of educators contributing to the module will be mentoring a capstone, a phenomenal "cultural" shift given we are a research-intensive institution, with the expectation students will gain a research experience through their project (Figure 1).

Innovation and impact:

Historically, few Bioscience students have undertaken schools or education projects, and these remained very much research-focused[2,9]. My innovative approach is recognising the concept and substantial benefits of capstones, and being the first (in 2005) to introduce them into the UK Biosciences. The benefits to staff and students are through innovative learning design, a total change in language and relationships, and the broad portfolio of opportunities created.

I have broadened the reach of my work beyond my own institution. In huge demand from educators seeking to implement capstones into their programmes, from 2017-early2020 I delivered keynotes or workshops at 11 Universities and 5 national or international educational conferences:

"You have inspired quite the debate back here and I am confident that this will affect change for the betterment of our students"
(Director of Learning and Teaching, Keele)

Students want capstones in their programmes:

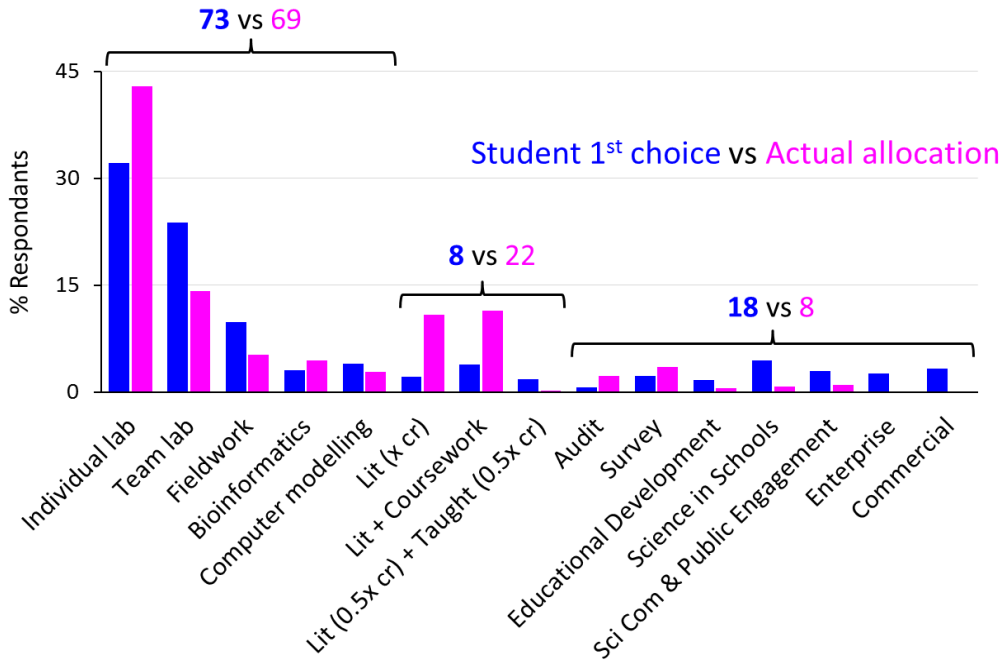


Figure 2: Student want more capstone opportunities in their programmes. Survey of 546 Level 6 students from 28 UK Bioscience Faculties of their first choice of project (blue) and what they were allocated (pink). Taken from Lewis *et al*. (2017)[2].

I was invited to revise the RSoB's project accreditation criterion[15]. I've directly informed the broadening of the IBMS's criteria[16].

Covid occurred and my **impact went stratospheric** as Bioscience educators globally struggled to provide alternatives to research projects. Sue Jones (York StJohn), Michelle Payne (Sunderland) and myself, with support from HUBS and HUCBMS, co-delivered

three interactive online workshops for 250 educators from as far afield as Canada and Australia. I delivered further six in the UK and Eire.

The screencasts[17] and "How to Do It"[12.13] guides I created and proactively shared have had **11,000 views** from over **50 Countries** in 9 months.

"*Most valuable document to guide us in our educational efforts on the African continent*"
(Professor, South Africa)

"On behalf of Bioscience educators across Ireland, thank you for your generosity. Your sharing of your excellent resources and expertise has enabled us to deliver alternatives to wet lab-based projects during this Covid pandemic"
(Associate Head of School, Dublin)

Seventy-one UK and 6 overseas Bioscience Schools have **introduced capstones** into their programmes in 2020-21. More importantly, these changes are here to stay. I have opened up colleagues eyes to the potential of capstones.

"*You have been an inspiration to me personally to rethink the objectives of final-year projects, and for that I am truly grateful*"
(Professor, Eire)

"*Becoming a cornerstone on which a full curriculum review is being built*"
(Workshop Participant)

Reflections:

Introducing, refining and disseminating my approach to capstones has been the most challenging but also the **most rewarding educational intervention** I have implemented. The colossal benefit and impact it has had on myself, students, colleagues, Institution, the global Bioscience community and Society is beyond my wildest dreams.

I have successfully persuaded:

- My entire School of the academic equivalence of capstones, and to join me in this venture;
- Students that laboratory projects weren't the "Gold Standard", and the unique benefits of capstones;
- My university to re-think the "Leeds Curriculum" project criterion[18]
- The RSoB[15] and IBMS[16] to embrace the concept of the capstone and broaden their accreditation criteria;
- Colleagues globally to introduce capstones into their programmes.

I'm immensely proud of the growing international community of practice I've created (Figure 3).

Figure 3: Evolving Community of Practice. The core Leeds team, local partners and a developing nationally and international community

I intend to pro-actively develop this community going forward. Collectively progressively realising the full potential of capstones for students, Institutions and Society. My ultimate goal, interdisciplinary, TNE capstones which address global grand challenges and UN SDGs.

(1579 words excluding legends)

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International:

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National:

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