CO-ORDINATED DEVELOPMENT STRENGTHENS THE THROUGH-LINE IN CONNECTED MODULES

Rebecca Yerworth[1,*], Anne Vanhoestenberghe[1,2] Adam Gibson[1]

[1] Dept Medical Physics and Biomedical Engineering, UCL
[2]Aspire Centre for Rehabilitation Engineering and Assistive Technology, UCL

Abstract: Many degree programs teach core topics over several modules spanning 2 or 3 years (e.g. "Introduction" and "Advanced"). Even if "Introduction" is a pre-requisite for "Advanced", students and staff may not fully recognise the connections between them. In addition, students often compartmentalise material and don't apply it elsewhere. Student feedback can therefore lead staff to develop new resources and re-teach material. UCL's Biomedical Engineering programmes include a theme of Medical Electronics that spans five modules across four years. Some modules are explicitly focused on medical instrumentation, others only partially. The teaching team has created a through-line of enquiry by explicitly discussing the links between the modules and collaboratively designing content (lectures and practicals), to emphasise connections. This reinforces the relevance of skills developed in the other modules. Re-teaching is replaced by referencing, specifically referring to previously taught material and shared resources. An additional level of complexity arises because some modules contribute to other degree programmes. By applying the same collaborative principles with staff on those programmes, we have been able to unify the experience across programmes and capitalise on the mixed cohorts to encourage student interactions across subjects and perspectives. Staff and students have commented positively on the benefits of the explicit connections between modules and we have seen an improved performance in a practical instrumentation project, relative to previous years. We will discuss the challenges, lessons learnt and examples of how student performance has improved as we iteratively develop the interconnected modules.

Keywords; connected curriculum, educational through-line, engineering education, Biomedical Engineering.

**Correspondence to: R.J. Yerworth, Dept Medical Physics and Biomedical Engineering, University College London, England. E-mail: r.yerworth@ucl.ac.uk*

1. INTRODUCTION

1.1 Connected curriculum

In 2015 the "connected curriculum" framework (Fung 2017) was launched at the UCL Teaching and Learning conference (UCL, 2015). This expressed the need for connectedness within university education through six interrelated dimensions, the two most relevant to this paper being: "A throughline of research activity is built into each programme" and "Students make

connections across subjects and out to the world". These sentiments resonated with the authors, who were then developing a new degree programme, which they envisaged to be a coherent journey, albeit subdivided into modules for logistical reasons. Within our vision for the programme, we identified several strands, general topics that would be taught across multiple modules. One strand was *professional skills*, developed in partnership with a faculty-wide initiative: the "*Integrated Engineering Program*" (Bains *et al.* 2015). The other strands were discipline specific. Now, 4 years after the first cohort of students started, we reflect on what we have achieved, sharing insights into the strategies, effort and team work required to get it to the current stage, and the work that remains to be done. Whilst our case study relates to one discipline-specific strand, of one engineering programme at UCL, the lessons learned are much more broadly applicable.

2. *STRATEGIES & CHALLENGES*

2.1 Developing the curriculum

In her book on the Connected Curriculum, Fung (Fung 2017, p75) challenges programme developers to ask "When and how are we empowering students to make explicit connections between apparently disparate elements of the programme(s)?" and "Does the progression of student assessments, in terms of the content of what is being assessed, look 'joined up'?". Fung goes on to emphasise the importance of the whole programme team recognising the importance of this joined up thinking, rather than just thinking about 'their' module.

We asked ourselves those questions, and found that, even with key members of staff fully ascribing to these aims, such a process is not without challenges.

2.2 Working with external constraints

A multidisciplinary programme can benefit from teaching expertise supplied by other departments, in the form of sharing pre-existing modules. This means that students benefit from research-based education provided by discipline-specific experts. However, even with a detailed copy of the syllabus and learning objectives, it can be difficult to provide the preparatory learning that the module organisers are expecting. Additionally, one may have to design the programme around what the external module organisers have already decided to include. With good communication and some creative thinking, some of this can be mitigated, as described in the case study below, so that the advantages of shared modules are maximised and disadvantages minimised.

2.3 Logistics of change

The content of degree programs changes over time, partly to keep it up-to-date with respect to new research and changes in wider society, but also because good education practitioners are always reflecting on their course and seeking to improve it. As a consequence, content may be added or reordered, with implications across modules, and even year groups. Sometimes a short-term increase in work load is required to achieve the change, in others a two stage process may be required, taking two years to fully affect the change. For example, it may be necessary to add a topic to the 1st year syllabus, as a pre-requisite for material to be taught in the second year. The

change can be made immediately for the 1st year students, but the existing 2nd years need the material as well, so for one year, it has to be squeezed into a 2nd year module. This may have to be at the expense of another 2nd year topic, which likewise has to be condensed for one year.

If teaching staff do not feel supported in initiating discussions about external changes that impact on their own material, the modules can become progressively more disconnected, and a programme that was conceived as integrated can become disjointed. We must however recognise the risk of the opposite excess, that some teaching staff may become over-enthusiastic about implementing considerable changes every year. One solution is for a member of staff to have overall responsibility for a programme or part of a programme. This person should be familiar with the content of the modules making up that programme strand, and able to suggest the most efficient way to implement the proposed improvement across the modules affected.

2.4 Staff vision and motivation

Having many research-focused staff teach on a programme is beneficial, in fact Fung *et al*. have identified it as an important feature of a connected curriculum, stating that "Students [should] connect with staff and their world-leading research" (Fung, 2017). For some of these staff, teaching may be a chore they have to do, rather than a passion. This, combined with busy work schedules, means that some staff are reluctant, too weary, or not interested in, engaging in inter module dialogues. This may even be the case within a module, with staff wanting to be given a set of learning objectives, and then left to be in control of "their bit". Related to this, is the issue of intellectual property, both the sense of "I've got this resource to just how I like it, and don't want it changed" and "I created this, own this, and you have no right to use it". It is not often that these sentiments are expressed as bluntly as this, and they may in fact be partly subconscious, but it is helpful to be aware of this issue when asking staff to change to a more collaborative way of working.

The programme leader needs to be aware of what all the contributors are doing but there is a fine balancing act needed to allow people sufficient academic freedom, trusting to their wisdom and professionalism that they will create something fit for purpose, and providing sufficient guidance/leadership to produce a coherent, joined up, output, without becoming a control freak or dictator.

2.5 Welcoming others

We have discussed the merits of sending students to another department for teaching; there are also benefits in receiving students from other departments. A broad range of expertise and interests can make class discussions more rewarding, broadening the perspectives of each group of students, and stimulating multidisciplinary collaboration. Ideally programmes that share modules would be developed in tandem, with the receiving department contributing to the planning of the sending departments preceding modules, or even contributing relevant teaching. Alongside this, the receiving department's lecturers would do well to familiarise themselves with the overall aims of the sending programme, and developed their teaching with the needs of both sets of students in mind. This will enable appropriate links to be made to both wider programs, and reduced the sense of being an interloper/visitor on the module.

3. *CASE STUDY: BIOMEDICAL ENGINEERING*

3.1 Overview of the curriculum

Biomedical Engineering (BME) is a multidisciplinary subject spanning electronics, mechanics, medical sciences and more (Anscombe 2011). Like the other strands, the medical electronics (ME) strand is woven throughout the programme, through modules dedicated to the topic, modules which relate and apply ME to a specific area, and others focussed on practical project work. There are five main modules which involve ME and at least 3 substantial group projects (Table 1). In addition, there are several other modules where relevant links should be established (e.g. Computing in Medicine, in year 3). Each of the three projects listed was careful chosen to build on skills and knowledge obtained from the preceding and parallel taught modules. The modules and projects listed in Table 1 account for one quarter of the BEng programme.

	Taught Modules	Group projects
Year 1, Term1	Cardiac Engineering	Challenge 2[1]
Year 1, Term 2	Medical Instrumentation 1	Scenario (Smart clothing)[2]
Year 2, Term 1	Clinical Engineering	Scenario (Regaining control)[2]
Year 2, Term 2	Medical Instrumentation 2	
Year 3, Term 1		
Year 3, Term 2	Medical Electronics & Neuro-Engineering	

Table 1 Map of Electronics & Medical instrumentation in Biomedical Engineering Degree.

3.2 External modules

Taking into account the deliberately small size of the first cohort (12 students), and the number of new modules which needed to be developed, a pragmatic decision was made to initially replace the planned Medical Instrumentation modules with two introductory level, general electronics modules taken together with first year electronics engineering students and taught by UCL's Electronic and Electrical Engineering Department. Thus the first couple of cohorts of students took two modules, offered by another department, in the second term of the first year instead of Medical Instrumentation 1&2.

The external modules were part of a coherent programme focused, as a whole, on training students to become electrical engineers. Taking two of these modules in isolation from the rest of that programme left our students unsatisfied. They commented on the lack of relevance to their degree and that the modules felt disconnected: isolated silos of learning. The students were looking for the throughline and not finding it. In addition, the students were coming out of the external modules with a good knowledge of electronics, but not the more general instrumentation development skills needed by biomedical engineers.

[1] A 5 week group project, running parallel to taught modules, where students worked alongside students from other engineering discipline, to develop the design for a vaccine production plant, each student working on a subtask relevant to their degree program.

[2] "Scenarios" are intensive one week group projects, during which all other teaching stops.

Replacing the external modules by developing Medical Instrumentation I (and II) offered many advantages: we could tailor the content more specifically to the needs of biomedical engineers, based on the experience of the module lead (an electronics engineer with 15 years' experience in medical electronics); rebalance the introductory module, and, very importantly, we could strengthen the links between all the modules within the biomedical engineering programme. To this end the relevant module leads have spent considerable time briefing each other about the content of their modules and drawing up a table of what is taught where. Emails would go to and fro with topics like "By year 2, have the students heard of….", or "For info, the 1st years use this or that knowledge in project ….". This work is already paying off, with a noticeable improvement in the practical electronics skills of the students, as demonstrated by the markedly increased competence and success of the most recent students doing the *regaining control* project relative to previous year groups.

Another substantial cross-module collaboration, arising from this, relates to training students in how to keep a "lab notebook". This involves continuous formative assessment across 3 modules, using the same marking criteria, with a record sheet that highlights progress, not just the students' current level of achievement. Initial feedback indicates that this has been received well by staff and students, and allows help to be targeted at the weaker students.

Another side effect of swapping to Medical Instrumentation I&II was their location on the time table – it made pedagogic sense to spread them over two years, rather than teach both together in one term like the external modules they replaced, but this meant another module had to move from 2nd year to 1st year. Reverberations of our changes were impacting staff outside of the ME strand, as this change meant that, for one year, two cohorts of BME students needed to be taught the same module (both 1st and 2nd years), significantly increasing the workload for the affected lecturers, who fortunately were understanding and willing to take this on.

3.3 Creating new modules, and prerequisites

Cardiac engineering was the first module from electronics/instrumentation strand to be developed specifically for the BME degree. It was envisaged as a showcase of the breath of biomedical engineering, covering mechanics, electrical engineering and anatomy & physiology. To connect these elements together was a challenge in itself, so we made the decision that all three lecturers would focus on and apply the learning to one body system, hence the name *Cardiac* Engineering (Yerworth et al. 2015).

Choosing where to teach topics is a constrained optimisation problem and strategic compromises have to be made. So a conversation which started with "oh no… you not thinking of moving [topic x] to the 2nd year are you…. I was bargaining on those skills being used in *smart clothing*!" ended up with an agreement that the topic would effectively be taught via flipped learning. The theory and detailed explanations would be taught in year two, referring back to the experiential introduction to the topic in *smart clothing*. The only changes needed in *smart clothing* were some tweaks to the marking criteria, adjusting the markers expectations of what the students would achieve, and some 'link forward' comments in the student's briefing sessions. However not all conversations were as constructive and at one stage a lecturer taught almost the same material, in two separate modules - to the same group of students! Solving this is top on our priority list.

3.4 Opening modules to other programmes and sharing resources

Last academic year students from another academic programme joined Medical Instrumentation I. We drew on all we had learnt previously, with respect to use of external modules, to optimise the experience of these students, without diminishing that of the BME students. One way we did this was to contribute to the planning of their first year first term module, the one that, like Cardiac Engineering, serves as both an introduction to the whole degree, and preparation for 2nd term modules. The outcome was that we became responsible for preparing and delivering a section of this module, dedicated to preparing the students for Medical Instrumentation 1. Alongside this, Medical Instrumentation I was developed with the needs of both sets of students in mind. This enabled appropriate links to be made to both wider programs, and reduced the sense of being an interloper/visitor on the module.

Along the way we discussed how to link to resources which are introduced in another module. Two methods were explored, with complementary strengths and weaknesses:

- Shared generic Moodle[3] resource page
- Link to the other modules' Moodle page, or relevant Moodle Snapshot (static archived Moodle page), if the module is from previous year

It was decided that when referring to past practicals or assessed work the relevant, module specific, Moodle page should be linked to, but generic reference material (e.g. guides on how to use lab equipment) should be placed on a common resources page. Students referred to the resources on the generic Moodle resource page without being reminded during the *scenarios,* for example, indicating that they found this useful.

4. DISCUSSION

We have already seen many benefits to this collaborative, programme wide, approach, but putting it in to practice has not been easy. It is also an ongoing process, with further iterations of improvement planned for the coming year.

It is has proved extremely important that module leaders and lecturers have a shared vision for the programme as a whole, and a mutual trust, and willingness to be venerable with each other, in the sense both of giving access to resources they have developed, and receiving constructive criticism. Where this has happened the connections between modules are strong, but we need to work on encouraging and supporting more staff to share this vision.

We also recommend that, where there are subjects running through multiple modules, one person is made responsible for coordinating this collaboration. This emphasizes the departmental commitment to having a connected curriculum, and helps ensure that inter-module conversations happen.

[3] Moodle is an online virtual learning platform, with a separate area for each course, to which staff can add documents, quizzes and other resources, as well as hosting discussion forums and handling assignment submission.

We trust that in sharing our experiences others may be encouraged to start inter-module dialogues with their colleges and to navigate more easily some of the obstacles. Even small steps can make a positive difference to how students perceive the context of modules. We wish you well in your endeavours.

5. REFERENCES

Anscome, N., 2011. Studying BME in the United Kingdom. *IEEE Pulse 12-18*

Bains, S., Mitchell, J.E., Nyamapfene, A., and Tilley, E. (2015). Work in progress: Multi-displinary curriculum review of engineering education. UCL's Integrated Engineering Programme. In 2015 IEEE Global Engineering Education Conference (EDUCON), pp. 844–846.

Fung, D., 2017. *A Connected Curriculum for Higher Education.* London: UCL Press.

UCL, 2015., *UCL Teaching and Learning Conference 2015*, University College London, London.
Url: https://www.ucl.ac.uk/teaching-learning/news-events/ucl-teaching-and-learning-conference/ucl-teaching-and-learning-conference-2015

Yerworth, R., Gibson, A., Garcia, P., 2015. Focusing the general: putting the heart in an introductory biomedical engineering module', *UCL Teaching and Learning Conference*, London. 13 April 2015.