

Enhancing Engineering Education through Industry Integration

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ABSTRACT

The postgraduate professional practice module at University College London (UCL) has been designed with a range of guest speakers to equip research students for the challenges of the 4th industrial revolution (“Industry 4.0”). This module supports the teaching of software engineering research students within the Department of Computer Science.

The focus of the academic lectures are project management skills; providing an understanding of teamwork and leadership, and an appreciation of the importance of ethics, inclusion and diversity. The teaching is aligned with the aims of Responsible Research and Innovation (RRI) to foster inclusion and sustainability.

The industry guest speakers cover a range of topics including: IoT, cloud computing, microservice architecture, security, and cognitive computing. The module currently integrates guest talks from Fujitsu and HSBC covering quantum technologies; microservice architecture and cloud-native development, HPC cloud provision, GDPR, and sustainability from RedHat, Form3, NGINX, and Verne Global. Detailed coverage of: distributed ledger technologies (DLTs) from Digital Asset; team organisation from ThoughtWorks; and cognitive computing, data architectures, and engineering trends from Instana, NetApp, and IBM.

It was a considerable challenge to integrate these guest speaker talks with academic lectures, so that the module was delivered in a logical sequence. Without student-generated material and surveys to gauge the extent of understanding before each topic is covered, it would have been far more difficult to deliver this short module. Student feedback indicates that guest lectures help prepare them for their research projects and discussions following talks provide a valuable opportunity for professional-instrumental networking.

1 INTRODUCTION

The accelerating technological change brought on by the 4th industrial revolution is having a major impact on the labour market, and creating an “annual shortfall of 59,000 engineering graduates and technicians to fill core engineering roles” in the UK [1]. The CIO 2018 survey [2] highlights that particular skills shortages are in areas such as data analytics, AI, technical and enterprise architecture, and project management. In these areas, many organisations have difficulty hiring; the concern is exemplified by Coindesk in their coverage of difficulty in attracting developers for blockchain technologies [3].

It is also recognised that there is a shortage of engineers across Europe. Metz has outlined that as organisations adopt new technologies, they are finding it harder to recruit qualified engineers and researchers [4]. Telukdarie & Sishi [5] describe the 4th industrial revolution of smart industrial environments as, “systems, smart devices, and products communicate and share information in real-time”; a framework of integrated layers creating a value chain for industry. They outline that, data analytics, IoT, cloud, and Cyber-Physical Systems (CPS) are enablers for Industry 4.0. Xu et al. [6] go further in encompassing in their discussion of Industry 4.0, enabling technologies such as blockchain and emergent technologies which will integrate industrial manufacturing systems and change the world of work. Klaus Swab, the executive chairman of the World Economic Forum in his book, the 4th Industrial Revolution [7], considers that all disciplines, economies, industries will be affected.

The Royal Academy of Engineering (RAEng) recommend there should be a “radical increase in the involvement of industry in university education”, including in the design of university engineering courses [8]. The RAEng also cite examples of good practice where business school staff are involved in the teaching of engineering courses to widen their understanding, and students are involved in addressing realworld challenges [9]. The RAEng consider that guest lectures by industry leaders should be incorporated into engineering modules. Additionally, this provides realworld contexts for the application of theory, and allows students to appreciate alternative perspectives, both of which potentially increase student engagement.

Fung argues that there should not be a conflict between the needs of industry and research in universities [10]. Both need the skills of critical thinking, and the analysis of new technologies and their impact on society. The Humboltian philosophy, that teaching and research should be inexorably linked, and that students learn more effectively via research-based teaching forms the basis of the Connected Curriculum at UCL [11]. The core principle of this curriculum initiative is that students learn through research and enquiry. One of the six dimensions of this curriculum is that students connect academic learning with workplace skills, which can partly be addressed by industry guest lectures.

2 BACKGROUND

This paper outlines the ongoing development of an MSc professional practice module within the faculty of Engineering Sciences at UCL. It covers the opportunities and challenges in combining a series of industry talks with academic lectures. Two cohorts of students take this module; one class majoring in Financial Software Engineering and the other majoring in Software Systems Engineering. The guest speaker talks, which take up 20 hours, are closely aligned to 10 hours of project management teaching, which includes application development and enterprise delivery.

This module is designed to widen students’ knowledge of engineering, alongside their specialism of software engineering. In effect, it is helping to create, what some call “T-shaped engineers” [12]. The module includes topics that all genders have declared an interest in, creating a more inclusive environment [13].

The module aims are to also provide industry perspectives alongside project management theory, and to help students prepare for their research projects with industry partners, and their professional careers. There has also been a shift in focus for this module, from primarily academic report writing to increase the coverage of business reports and presentations emphasising the economic and humanitarian value of student research.

At the core of this postgraduate module is the Engineering and Physical Research Council's (EPSRC's) approach to Responsible Research and Innovation (RRI) [14]. RRI is also embedded in the European Commission's Horizon 2020 programme which aims to "foster the design of inclusive and sustainable research and innovation" [15]. The module teaching includes the EPSRC's Anticipate, Reflect, Engage and Act (AREA) framework [16], to ensure that students continuously evaluate their projects. The analysis of this framework is in the form of process, product, purpose, and people [17], so that all facets are considered ethically and responsibly for the benefit of society.

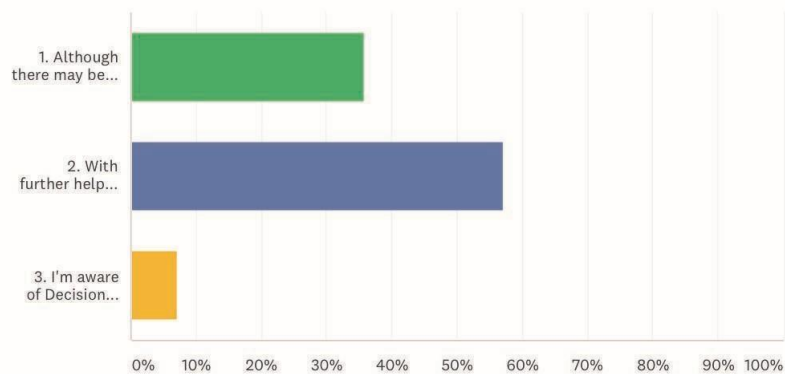
3 DESIGN AND DELIVERY OF THE MODULE

Examples from previous student research projects are outlined at the start of this module. These are currently based on machine learning research, to provide pedestrians and cyclists lower air pollution routes in cities [18]. These are included to show how previous students have structured their work and the impact their research has made. These examples provide relevant material, and show a clear relationship to both the EPSRC's Responsible Research and Innovation framework and the UN's sustainability goals [19]. This creates an atmosphere of shared endeavour to research-led teaching and solving humanitarian problems. This also provides an opportunity to highlight engineering topics such as health and sustainability, which female students, in particular, have indicated they would like to study [13]. It is also a useful mechanism to show the different approaches student teams have taken for their research projects; highlighting the value of considering other stakeholders' perspectives.

The theme of acknowledging the value of everyone's contribution and inclusion also runs throughout the course. This is emphasised in the lecture focusing on teamwork, inclusion and diversity, and that optimal solutions come from a diverse team with a range of experiences. Encouraging different perspectives and understanding of bias also helps support the concept of neurodiversity: that differences in communication, such as with autism, should be supported and appreciated [20].

How likely are you to document architecture decisions?

Answered: 42 Skipped: 0



ANSWER CHOICES	RESPONSES
1. Although there may be some industry approaches regarding architecture decisions I would not necessarily look at these, but would at least document the problem, a solution and an alternative.	35.71% 15
2. With further help or working as a team I feel confident I could adapt an appropriate method, document a solution, outline an alternative and describe why our chosen solution was adopted.	57.14% 24
3. I'm aware of Decision Centric Architecture Reviews (DCAR) or an alternative method and may reference this and adapt this method so that the time involved in using this is not an overhead to the project. As well as the solution and alternative I may also include forces in favour of our solution as well as those against.	7.14% 3
TOTAL	42

Fig. 1. Choices provided by students attending the Professional Practice module academic year 2017-18. Several students from the School of Management also attend selected lectures. N=42.

Providing feedback is essential to improve learning, however, some students may take constructive comments on their work personally. Goldsmith [21] suggests that if the lecturer discusses with the class something that will be taught, it avoids any potential criticism of students and creates a more positive learning atmosphere. Feedback requires the student to have some knowledge of the topic, whereas “feedforward just requires considering the question and having innovative ideas to solve the task or think about it in different ways” [21]. In addition, the answers they provide will be naturally aligned to their way of thinking. Discussing the results of an anonymous questionnaire in class and considering suggestions is one way to inspire ideas and connect concepts.

Prior to topics being covered students are asked about their level of understanding via electronic surveys using the open-source web application SurveyMonkey. *Fig.1* illustrates an example of the answers, to questions asked before the software architecture topic. In this question, students are asked how they would approach their research projects and their awareness of software architecture frameworks. The answers provided, as in *Fig.1* are not meant to be right or wrong, but give different views for discussion. This gives both valuable insights for the lecturer and the industry guest speaker, to better plan the content for their forthcoming talks. This information is further enhanced by discussions within Moodle, the electronic module forum for the class.

4 CHALLENGES

Guest speakers often find the syllabus outlines are insufficient to gain an understanding of the students' background knowledge. In planning talks, industry speakers typically ask the lecturer about the students' awareness of programming languages and patterns, industry and project experience, as well as concepts and frameworks. The planning problem for this module is complicated by there being two cohorts of students. A carefully designed set of questions for the class, via an electronic survey, to be completed before talks, helps ensure all students are considered when deciding the content. This has shown to help both the lecturer and industry practitioner in understanding the knowledge and experience the students are likely to have. This ensures that talks are pitched at an appropriate level, and topics that are well understood by students are not subject to extensive explanations.

It is also a challenge meeting the aspirations of both cohorts of students in the class and balancing the range of leading-edge engineering topics. As the first academic lecture was based on the project management and technology used for a humanitarian project the first guest talk covered a technology project in the financial markets. The lecturer and guest speaker co-planned a topic covering HPC quantum and Adjoint Algorithmic Differentiation (ADD). This talk included the necessity of Basel IV compliance and risk modelling, how sensitivities of financial instruments can be effectively modelled using ADD using coding examples, and how quantum annealer technologies provide an advantage. Since only two hours were allocated for this talk, it was important to ensure appropriate background coverage within the project management theory classes and that the programming languages were already covered within the software engineering modules. This material was designed to be further supported by discussions, addressing what a project manager needs to be aware of when resourcing such projects. This topic was also linked to the content of the talks covering quantum technologies from the guest speaker from Fujitsu, and HPC and sustainability from the speaker at Verne Global.

The greatest challenge is sourcing relevant and inspiring speakers. As with the findings of other academics in this area, one of the key challenges is the additional time this involves [22]. Allocating adequate time for this activity is important, as students appreciate talks covering leading-edge technologies that are related to their research projects:

“[The lecturer] managed to secure talks from incredible industry speakers who shared up-to-date, relevant knowledge on current topics.” Professional practice student academic year 2017-18

Planning the talks so they create a coherent module structure, and designing the talks with guest speakers, also takes time. This includes ensuring that guest speakers are aware of the generic module feedback, which typically shows an appreciation for real-world scenarios and live coding. One particular lecture, with student input, included a live demonstration of how the NGINX product protected a website from a denial-of-service (DoS) attack. A volunteer student in the class acted as the “hacker”, showing real-time how a website, specifically created for the talk, was protected from multiple attacks. Some students have commented that they particularly appreciate talks covering software they use within their project work:

"I especially appreciated the talks from Nginx and Chef, which are two companies with whose products I am intimately familiar with." Professional practice student academic year 2017-18

Not only do the students have a better understanding of these technologies, there is also a benefit from more engaging teaching.

As guest speakers are typically invited during the autumn semester, after the examination questions have been set, students are not specifically examined on the content external speakers deliver. However, some students have indicated that they would like to write a report or dissertation on these leading technologies:

"I think having the lecturers from industry was both very interesting and really useful. Some of those lecturers have been the highlights of my time at UCL. Maybe have an assignment that allows students to select 3 of the visiting talks then write a short report on each say 500 words critically analysing the benefits and possible complications around the topic. That way you wouldn't need a 100% exam." Professional practice student academic year 2017-18

Engineers need to adapt to an ever-changing environment. Johnstone argues that engineers need to take on a wider range of skills including project management, and that they need to keep learning [23]. This is also emphasised by the use of term "learning animals" [24], used by several technology organisations, and by Eric Schmidt, the executive chairman for Alphabet, the holding company for Google.

Guest speakers are selected for their technical excellence, their wish to help our students and the potential for student research projects. Managing guest speakers, requires timely communications via email and phone, to address their questions and provide background information. Talks are typically planned with guest speakers during the autumn term and the content reviewed ideally at least a month before delivery. Ensuring that their slides are ready at least a week beforehand so that students can review these if they wish sometimes requires tactful reminders, as guest speakers often have numerous priorities within their organisations.

Before guest talks, students are provided with details of the forthcoming speakers, their biography, technical papers and discussion blogs they have written. This enables students to develop a better understanding of the topics and also encourages them to exchange ideas. To facilitate this further, guest speakers are encouraged to leave at least 20 minutes available after their talks for further questions, and discussions. Guest speakers ensure they have their contact details within their slides, which are made available to students via the course Moodle site. Many guest speakers invite students to contact them if they wish to discuss technologies or arrange an industry visit. Although students often engage in social media this is not always the case for professional networking. These invitations provide a less daunting way in which students feel they can approach speakers and students often continue discussions and networking after their talks.

5 CONCLUSIONS AND FURTHER WORK

Providing technical discussion papers within the course and guest speakers providing an invitation for further discussions helps create a foundation for networking with the speakers and organisations they represent. This extends opportunities for students to develop their instrumental networks: social ties to support their professional goals. Instrumental networks are important for cooperation at work [25]; they also allow individuals to create connections to further their careers. However, Gaughan et al. have found that women's professional networks which favour advice networks, are less likely to support academic activity [26]. These findings provide support to the idea that females should be encouraged to develop instrumental networks.

Previous research by the author indicates that female students are keen to explore external industry contacts within their studies [13]. This was particularly true within areas of their interest, such as research with positive environmental and humanitarian impact. Ensuring speakers cover these areas during the module is therefore important. Integrating guest speakers within the module, may increase the students' instrumental networks, especially as guest speakers often extend invitations for industry visits or continued professional connections. This may create beneficial career effects for all students. Hopefully, this will also help address the imbalance in types of networks females are reported to have, and therefore be a positive move, in supporting female research students' careers:

"My favourite course on the degree, it had leading companies come in and talk through their process and how these processes got implemented, very insightful and super useful." Professional practice student academic year 2017-18

Even though numerous reports cite the benefit of industry involvement for students [8], in terms of both research and employment prospects, there is, however, currently limited research that covers how industry guest speakers should be effectively integrated within a programme. In addition, there is limited research particularly in the way engineering courses, covering recent advances associated with Industry 4.0, have industry speakers integrated. This is partly due to the rapid developments within the associated areas such as: cloud, IoT and edge, HPC and quantum technologies, and cognitive computing.

May-Newman and Cornwall [27] outline problems in engineering where the industry speaker may not have the pedagogic experience, or where the academic may not have specific practical experience in the topic. Providing industry experts in each of the different fields of industry can ensure that the topic is always delivered by an expert and a range of real-world research projects are included.

Research has shown sourcing speakers is time-consuming and is often left to key individuals [22]. Fung [10] points out this role should be properly resourced, and the RAEng [8] indicate this should be more of a joint venture, between industry and universities, particularly in curriculum design and delivery of content. Research is also needed on how an optimal balance is achieved in resourcing guest speakers; between individuals versus a central resource. In leaving individuals to invite speakers, there are the risks associated with the sole point of contact. Often guest speakers deliver

talks for altruistic reasons, including to give “something back” and to help future generations. However, it needs to be also recognised that guest speakers will often help simply because of the valued professional relationship they have built up with the person who has invited them.

It is important to integrate external speakers, not only for the technology insights they provide but also to help students consider different perspectives. To do this effectively, research has shown [28] that having a feedforward approach to ascertain how comfortable or what experience students have of a topic is a useful approach. Sharing this knowledge with guest speakers has not only shown that the speakers are valuable members of the teaching community but has also enabled more effective module development and alignment with the ethos of UCL’s connected curriculum initiative. Co-planning with this feedforward information has also created a logical course structure, a valuable illustration to students of industry-academic collaboration.

Research has shown that organisations need to create opportunities for instrumental networking, as the least likely to engage in this activity are the individuals that need this the most [29]. Guest speakers inviting further questions and opportunities for visits after their talks is one approach to breaking barriers down and increasing networking opportunities. These invitations may also help create an atmosphere of spontaneous networking, making it more likely that students will feel comfortable in continuing discussions with the speakers. Casciaro et al. [29] discuss that facilitating such networking contexts where the expectations are clear may not induce the feeling of being morally compromised which can be associated with instrumental networking. Further research is needed to verify this. However, these networking opportunities following guest speaker talks are one approach to help students develop their professional networks.

There need not be a conflict between preparing students for the world of work and the needs of research. Both require an openness for dialogue, and an ability to critically appraise ideas and values. Both require being able to see others’ perspectives and the ability to articulate concepts and ideas and progress society for the greater good.

If we are to expect students to engage in research that benefits industry and society, we need reciprocal arrangements from industry. With an increasingly interconnected world brought about by the advances of Industry 4.0, it is more important than ever, that students have an opportunity to learn first-hand from industry leaders driving these technologies. Integrating guest speaker talks within university research-led teaching programmes is one way to provide real-world examples, and enhance students’ critical thinking and knowledge of new technologies. Students with this industry and university research-led experience will be better able to solve humanitarian problems and create a more sustainable future.

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