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Advanced research projects in taught Master's level programmes: a case study

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ABSTRACT

Research-based education is essential to provide cutting-edge content and equip students with the necessary research skills for their future careers. In this practice paper we presented our work of developing and delivering a new module of advanced research projects in a taught Master's programme to help students develop independent research skills and work collaboratively in a team to conduct thorough scientific investigations. Several important aspects of delivering this module, such as group allocation and project selection, assessments and supervision and scaffolding, are described in detail. The results showed that the quantity and quality of the research output produced by the group work was larger than the sum of the individual contributions.

INTRODUCTION

Master's level programmes normally have some elements of research in the curriculum to provide cutting-edge content and equip students with advanced research skills. The latter are crucial attributes of this level of education for many educational frameworks, such as subject benchmark statements, and often appear as specific learning outcomes in accrediting institutions. Research-based education at the Master's level can be implemented in various ways, and one of the most common ones is through research projects. Previously educators in higher education have shared experiences of conducting research-intensive projects at the Master's level (Bourlier et al., 2017; Knutson et al., 2014; Sarafoglou et al., 2020). Particularly, some areas that attracted attention included the acquisition of advanced research skills (Lundahl, 2008; Shostak et al., 2010), professional skills training for postgraduate students (Holland and Garfield, 2012), mentoring scheme (Feldman et al., 2013) and assessment design (Hammond, 2021; Le Boutillier et al., 2024). However, the acquisition of research capabilities has often been rated the lowest by Master's students (Bamber et al., 2019), which is understandable because research activities often involve uncertainties and risks to explore unknown territories, whereas traditional taught Master's programmes focus more on well-established content (Rickly and Cook, 2017). Moreover,

research-based education means not only that the teaching content is research-informed, but also that students are adequately supported and enabled to become researchers – to think like scientists (Hughes, 2019). Therefore, there is still urgent work that needs to be done to improve the way we integrate research into teaching at the Master's level. As an effort in this direction, this practice paper presents our work on developing and delivering a new module of advanced research projects for a taught Master's programme in Mechanical Engineering.

AIM AND OBJECTIVES

In 2023 UCL Mechanical Engineering launched a new taught Master's level (MSc) programme – Future Manufacturing and Nanoscale Engineering (FMNE) at UCL East, the brand new campus of UCL opened in the same year. FMNE is one of the new MSc programmes housed in UCL Manufacturing Futures Lab (MFL), with an overarching aim of integrating research and education in an interdisciplinary and collaborative environment.

The *Advanced Research Project* is the last module in this one-year programme, and it is worth 1/3 of the total credits; thus it has a significant impact on the overall learning experience and academic achievement of the students. In it, the students are engaged in a novel research project, combining design, characterisation and manufacturing of nano-engineered materials, and their applications in real-world engineering problems. One of the overarching aims is to help students develop independent research skills based on the integrated knowledge and techniques they learn from all other modules of this programme, and work collaboratively in a team to propose a research question and find answers by thorough scientific investigation, with focuses on novelty, originality and robustness.

The learning outcomes of the module are:

1. Formulate a novel research idea based on review of current literature.
2. Design a research methodology to answer the defined research question, accounting for: novelty, sustainability, practicality, resources, for future manufacturing and nanoscale engineering.
3. Demonstrate viability of proposed research methodology, e.g. risk management and data-driven evidence of decision making.
4. Demonstrate advanced knowledge and application of a variety of research techniques, both computational and experimental.
5. Disseminate effectively the research outcomes to a technical audience.

In this module, students work on advanced research projects in small groups of 2-3 students during Term 3 and the summer period (May-August). The project topics are provided by academics, students themselves or industry whenever possible, and supervised by academics in the department. The scope of projects can be computational, experimental or mixed. The students are evaluated on their group work and individual contribution. The key aspects of the detailed delivery of this module are described in the next section.

DELIVERY OF THE MODULE

Group allocation and project selection

We aim to create a learning environment through group work to mimic the contemporary practices of academic and industrial research. We keep the group size small (2-3 students) to make sure each student gets sufficient resources and supervision, and no students can hinder the progress of the team project, or "coast" through its duration. As this is the last module during the academic year, students have already known each other; therefore, we allow them to form their own groups based on common interests and compatible skill sets.

It is worth noting that project selection and group allocation are intertwined, because the process of exploring research interests overlaps with the process of finding collaborators that share similar interests and complementary skills. After project proposals are published, students can either express interests in proposals in a shared spreadsheet that is transparent to everyone and then form a group based on common interests, or form a group first based on compatible skill sets and then choose a project together. All project proposals are research-focused and collected from academics and industry collaborators; in addition, students can propose their own project ideas. We make sure the number of proposals is always greater than the number of groups to give students a wide range of choices.

As all projects are open-ended research projects, we encourage students to participate in developing and refining proposals, which include tailoring project scopes based on their specific interests and skills, and working with potential supervisors to develop detailed proposals from initial ideas. Research exposure is key in this process, so we organised research showcase events to connect students with supervisors, which not only help students better understand the details of projects but also help them develop creativity and future-facing visions.

Assessments

The overall strategy for the assessments in this module is to combine a wide variety of assessment types, e.g. written and oral, formative and summative, and group and individual . The assessment pattern and timeline are shown in Figure 1.

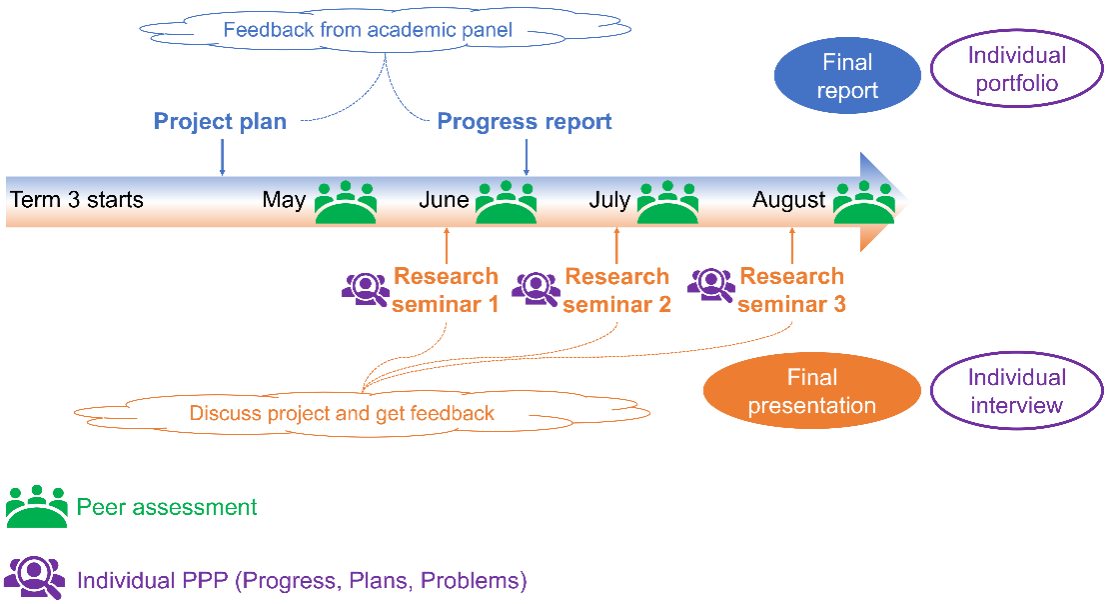

Figure 1: Overall assessment pattern and timeline.

The final summative assessments include both written and oral elements, which is common for assessing final projects at both undergraduate and postgraduate levels. Students are required to write a group report in the form of a research article and specify their individual contributions in individual portfolios. The oral element is a group presentation followed by an individual interview. The evaluation of reports and presentations involves both supervisors and second examiners. If we look at the spectrum of how students are assessed for final projects – at one end it is the teaching-focused undergraduate projects, which are normally assessed in panel sessions where similar projects are grouped together; at the other end, research-focused PhD examination often takes the form of individual sessions between the candidate and the panel, who examine both the thesis and the viva (e.g. in the UK system). We are somewhere in the middle – doing research in a taught Master's programme, so getting supervisors and hand-picked second examiners in the panel can provide more specific expertise to thoroughly assess the projects. Moreover, as the final reports are written in the form of a research article, we have developed a marking rubric that contains similar criteria to those used to assess a manuscript submitted to a scientific journal, and publication indicators (from reject to accept without revision) are added alongside the grading bands.

To help and support students to prepare for the final summative assessments with confidence, we have a series of formative assessments in place. Aligned with written assessment, groups need to submit a project plan in the early stage and a progress report in the middle of the project. These reports are assessed by an academic panel other than their supervisors, to give students feedback from the perspective of external experts. In line with oral assessment, we run monthly research seminars in the main project period (May – August), where students can present their work in a casual setting, like the coffee/tea break time in a conference. We give students the flexibility to use PowerPoint slides, show simple

plots or just talk because this way can help them gradually overcome the nervousness and become more confident and comfortable talking about their work. The research seminars not only help students develop presentation skills but also provide an opportunity for them to share experiences and get inspirations from others' work; as we know the project period can be a lonely place where the main interaction for students is with their supervisors. We also embedded journal clubs and invited academic guests to give students feedback in these seminars.

Although the projects are group-based work, we have clearly defined individual roles (similar to work packages in research projects) in every proposal, so students need to work both independently on their individual tasks and also collaboratively to integrate their findings. Mechanisms have also been created to assess individual contribution in group work, which is vital for fairly assessing student individual performance and making sure they only earn credits for their own work. For example, we use regular peer assessments for students to review every member in the group, including themselves, for peer feedback and self-reflection, which also helps supervisors identify under-performing students and intervene accordingly. Every individual student also needs to submit an entry in the PPP (Progress, Plans, Problems) project reporting framework every month, and they are interviewed individually after the final presentation.

Supervision and scaffolding

In this module students do research in groups so instead of one-to-one student-supervisor meetings, students have regular research group meetings with their supervisors. From the student's perspective this format enhances their communication skills of both listening and sharing ideas, which can help them learn how to discuss, debate, negotiate and compromise in a professional way. From the supervisor's perspective, especially for early career researchers, this is a good practice of leading a research group. Students can also learn some practical skills in such group meetings, such as data storage and sharing using online platform or service, which has become more and more common in workplaces.

Master's students in taught programmes generally lack in-dept previous experience in managing and executing research projects. Therefore, in addition to normal supervision we have provided the scaffolding support of professional skills and a research skill development scheme to help the students. In the aspect of professional skills, an earlier module in this MSc programme (Terms 1 and 2), named *Group Manufacturing Challenges*, provides continuous support through a series of sessions, including teamwork, literature review, referencing, academic writing and presentation, which cover transferrable skills that are not limited to one module but throughout the programme, even for future careers. Regarding research skills, journal clubs in monthly research seminars are one example to help students develop research mindsets and understand the criteria widely used to evaluate the quality of research. We also provide resources and training in academic integrity, resources (e.g. IT, lab space and procurement) and risk management, use of generative AI and sustainability. We encourage students to consider sustainability in two aspects in the projects: running the

project in a sustainable manner, e.g. reducing waste and recycling; and the wider impact of the project, e.g. contribution to UN sustainable goals.

KEY OUTCOMES

In the first year of running the module (2023-2024) all students passed the module. We compare this module with another module of individual projects at the same Master's level. From the quantity perspective, the final report/thesis of an individual report requires15-20 pages (excluding cover page, references and appendix), which is approximately equivalent to 4500-6000 words per student. In our module of group research projects (2-3 students each group), the maximum length of the final group report is 15000 words. Therefore, even just counting by words the workload is at the same level. From the quality perspective, we use two indicators. The first one is publications from student projects. Normally it is difficult for Master's students to publish their work mainly due to insufficient amount or depth caused by limited time. In this sense, group work provides an ideal opportunity to overcome such difficulty, because each student can focus on one specific aspect in the project and the combined effort could meet the standard for publication, which is very similar to the scenario of a research group where contributions come from multiple members and they share authorship to publish the work. In our first year's cohort, one (out of three) group published a conference paper, and we aim to continue encouraging and supporting students in these efforts. This proportion (1/3) is much higher than that in MSc individual projects, although it is worth noting that there is a big difference in cohort sizes (8 vs. about 200 students). The second indicator is the number of students continuing to pursue a research-focused degree, e.g. PhD. One student from our first year's cohort (2023-2024, eight students in total) has already started PhD research in a world-renowned institute; in the current cohort (nine students in total) at least one student has accepted the offer to pursue a PhD degree.

DISCUSSION AND REFLECTION

The design and delivery of this module are well received not only by students but also by supervisors and other academics involved. From the supervisor's perspective, a shared view is groups produce more work, both in terms of quantity and quality, than simply adding individual projects together. However, it was difficult to bring all students to the same level in a group, which caused problems in group dynamics. The easy solution (also what we adopted) is rewarding better-performing students and deducting marks from under-performing students. However, this does not provide a solution for supporting and encouraging those under-performing students to become more interested and engaged in research. Further research into stimulating Master's students' research interests and developing research skills is worth more investigation.

CONCLUSIONS

In this practice paper we presented our work of developing and delivering a new module of advanced research projects in a taught Master's programme, which aims to help students develop independent research skills and work collaboratively in a team to conduct thorough scientific investigation. We described several important aspects of delivering this module, such as group allocation and project selection, assessments and supervision and scaffolding, in detail. The results of student performance and supervisor reflection showed that group work produced more work and better quality of research than simply adding individual projects together.

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