PUTTING THE 'TECH' BACK INTO TEACHING TECHNICAL FUNDAMENTALS – UTILISING THE CDIO APPROACH

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ABSTRACT

The integration of practical skills with engineering theory are the foundation of the CDIO approach. However, challenges lie in rolling this out effectively in a university setting to large cohorts of students. This paper sets out to address how these challenges can be reduced to achieve CDIO standards 7, 9 & 10. Advancement of integrated learning experiences and enhancement of faculty competence and teaching competence requires input from staff members with extensive practical experience. As the changing landscape of engineering education moved towards prioritising an education based on maths, science and theory came at the cost of the fundamentals of practice. In addition, this caused a shift in the university faculty to a staff of academics with mostly research backgrounds and little industry experience. Academics who want to incorporate more CDIO elements to their modules must consider the practicalities of providing large numbers of students with safe and beneficial practical learning environments. This is where technical staff can bridge the gap in staff numbers and expertise. Technical staff possess the know-how and expertise of the skills being taught, alongside the health and safety awareness to get students involved in a safe and supportive way. While it is often argued that technical staff do not have any recognised teaching qualifications, the reality is that in the process of designing, developing and delivering practical workshops for large cohorts of students, technical staff are in effect undergoing teacher training through the very delivery of these modules in collaboration with academic staff. If this is viewed in a CDIO learning context as illustrated in this paper, the true potential of technical staff as educators could be realised. This could provide engineering faculties with more experienced, trained staff and serve to increase their compliance with CDIO Standards 7, 9 & 10.

KEYWORDS

Technicians, Technical Fundamentals, Practical Skills, Manufacturing Technology, Teacher Training, Standards: 7-10.

INTRODUCTION

The CDIO approach of Conceive – Design – Implement – Operate was created with the purpose of educating students to become successful engineers (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2014). This was a reaction to the changing landscape of engineering education which had moved away from a more practical technical lead pedagogy towards a fully theoretical scientific approach. This move, towards prioritising an education based on maths, science and theory, though valuable, came at the cost of the fundamentals of practice. It also caused a shift in the university faculty creating a staff of academics with mostly research backgrounds and little or no industry or professional engineering experience before entering academia and teaching. These practical skills and experience are the foundation of the CDIO approach and therefore require input from university staff members with extensive practical and technical experience. Accrediting bodies also require that students are provided with these types of modules to meet mandatory learning outcomes (Cairns et al, 2024).

Technical staff have been contributing to the delivery of engineering education since its inception as a technical degree. Engineering education in the UK, seen as growing from practical skilled crafts, was viewed as a secondary trade and entered the universities much later than in other European countries such as France (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2014). As the focus moved more towards a theoretical, science and research-based approach, the continued contribution of technicians became more invisible. However, this has changed in recent years as institutions, such as the authors', get on board with initiatives like The Technician Commitment, a UK wide initiative which is now getting more international recognition (Vere, 2024), and incorporate a CDIO approach into the syllabus. The core goals of the Technician Commitment are to ensure visibility, recognition, career development and sustainability for technicians working in higher education (HE). Technical staff are vital in the role of delivering practical skills. Giving students the opportunity to learn from experienced practitioners. These skills incorporate and apply the technical fundamentals that are often not retained when delivered only as transmissive learning. Despite this vital contribution in the delivery of education Wragg et al., (Wragg et al, 2023) state that technical staff's role within HE is still poorly understood and not widely recognised within their faculties.

Delivering CDIO modules to cohorts of 200+ students comes with its challenges. As student numbers increase this will only become more challenging (Cairns, Millen, Pick, & McCartan, 2024). This paper sets out to address how these challenges can be reduced to achieve better compliance with CDIO standards 7, 9 & 10. Academics who want to incorporate more CDIO elements to their modules must consider the practicalities of providing large numbers of students with safe and beneficial practical learning environments. This is where technical staff can bridge the gap in staff numbers and expertise to make these modules happen. Technical staff possess the know-how and expertise of the skills being taught alongside the health and safety awareness to get students involved in a safe and supported way.

Teaching is a discipline of its own. A separate skillset to both the practical and theoretical understanding of engineering. It is becoming more common for academic staff across universities to now undergo teacher training within the early years of their career such as a Post Graduate Certificate in Higher Education Teaching (PGCHET) in the UK (Kozanitis, et al., 2009). Savage, (2024), states in his chapter on Technicians as Educators that until recently the idea of technicians teaching was problematic, referencing the quote "you don't teach, you instruct" (Savage, 2024). The history behind this attitude is complex but includes the historical imbalance between the value placed on theoretical (mental) work and skilled (practical) work, despite, as Connelly states in his chapter on the history of technicians, the contextual

knowledge required for this skilled work, (Connelly, 2024), and the argument that technical staff do not receive formal training in the delivery of education. However, as this paper will argue, when viewed through the learning context of CDIO, technical staff are undergoing teacher training through the very delivery of these practical modules. Bui et al, (2025) proposed the CDIO approach as a context for teacher training because of its integration of theoretical knowledge with hands-on experiences, promoting active learning, problem-solving, and professional competency (Bui, Nguyen, Nguyen, & Nguyen, 2025).

Standard 10 of the CDIO approach is the Enhancement of Faculty Teaching. Power et al., (2019) wrote a paper on developing CDIO practitioners to address this standard. The paper suggests the gap be filled by postgraduate staff members by engaging them in formal teacher training at this stage of their career (Power, Tanner, Ryan, & Devitt, 2019). This works well to add to the cohort of staff who will deliver these modules with postgraduates well placed as an extension of academic staff to transfer and apply knowledge on theory during workshops. However, they are not best placed for transferring practical skills knowledge when compared to technical staff. In addition, the position of postgraduate is a stage in an academic career rather than a permanent role. These staff members will usually only spend a few short years in this role, and then new postgraduates will need to be trained. In engineering schools, technical staff are often full-time permanent members of staff. Recognising and investing in their educational contributions will have long term benefits for the whole school. New technical staff can build on this year upon year gaining valuable teacher training. Experienced technical staff already possess extensive teaching experience that isn't formally recognised by the University. Once this is recognised it can be better utilised for the benefit of all stakeholders involved in the CDIO approach.

BACKGROUND

What is a technician?

Wragg et al., (2023) state that because technicians occupy a huge range of roles and responsibilities within education and research, it is difficult to have one single definition (Wragg, Harris, Noyes, & Vere, 2023). However, they can be described as a highly skilled workforce with diverse expertise (Nottingham, et al., 2018). Table 1 adapted from Chapter 1 of Technicians in Higher Education and Research represents the varied roles and expertise of technicians highlighting seven key areas of responsibility (Wragg F. , 2024).

These responsibilities cover just some of the roles of technicians. A further definition in the chapter on defining technicians gives a more encompassing overview

"Technicians are trained and/or skilled in the techniques, tools and/or technology of their subject, providing the practical application of knowledge and/or the expertise to best utilise this practical application through managing, teaching, and/or training others to deliver it, and/or through maintaining and developing environments, standards, resources, and/or facilities required for this practical application to be delivered."

Multiple definitions are being included to illustrate the wide range of knowledge and responsibilities required by technical staff. As Winberg, (2021), states in her paper on The Making of Engineering Technicians, this is still a role not easily classified, disregarded by some and often misunderstood (Winberg, 2021).

Table 1: Variety of technical staff responsibilities, table adapted from (Wragg F. , 2024)

Preparing resources and materials	Operating equipment	**Research**	Training staff and students	Data analysis
Preparing resources and materials	Delivering instructions and teaching	**Teaching**	Providing 1-to-1 support and feedback	Patrol care of students
Arranging servicing	Preventative maintenance	**Maintenance**	Contractor checks	Fault finding
Carrying out audits	Statutory testing	**Health & Safety**	Writing risk assessments	Delivering training
Writing tenders	Budgetary planning	**Finance and Administration**	Purchasing and procurement	Asset registers
Management of infrastructure	Management of equipment and facilities	**Infrastructure**	Inspecting buildings	Planning new building projects and refurbishments
Inductions and training staff	HR processes	**People**	Pastoral care of staff	Line manager

What is their role in delivering education?

Technical staff play a significant role in the delivery of higher education and the enhancement of the student experience. The CDIO approach was born out a need for engineering graduates with better practical and interpersonal skills as detailed in Chapter 1 of Rethinking Engineering Education through feedback from industry on the desired attributes of an engineer (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2014). Practical modules where students learn how to carry out skilled work both individually and in collaboration with their classmates address some of these desired attributes. These modules are delivered in the most part by technical staff. The Wragg et al. paper on Technicians as Educators emphasises the importance of practice-oriented, skills-based knowledge to create 'employment ready' graduates (Wragg, Harris, Noyes, & Vere, 2023). Survey data from this paper, carried out with a cohort of 1760 technicians in HE across the UK, showed that 83% of technical staff in engineering are involved in teaching. However, of the teaching technicians within engineering, 70% had not received any training with only 9% receiving formally recognised teacher training. Engineering showed the lowest percent of teacher training provided across the range of disciplines surveyed. In addition to limited recognised teaching accreditations for their contribution to education, technical staff often also go uncredited in their research contributions (Iliffe, 2008). Another area within HE where technicians are often the first port of call is in supporting the mental health of students. A survey carried out in 2019 with a cohort of 735 technicians across the UK showed that 22% of respondents said they provide pastoral support for students, 44% said they had discussed personal problems with undergraduate students and 51% with postgraduates. 60% said they had been approached or had approached a student to discuss their mental health. Despite so many technicians providing this type of support 68% said they had not received any training or were aware that training was available (Nottingham, et al., 2018). This is a vital but invisible role carried out by these staff members, often outside their job description, which hugely contributes to student wellbeing and the delivery of education.

How can this be utilised when incorporating a CDIO approach?

Large classes present significant challenges for student engagement. The Finn et al., study on student behaviour in small classes confirms that reducing group size increases engagement (Finn, Pannozzo, & Achilles, 2003). Having small class numbers for practical

modules promotes student engagement and allows for more 1-2-1 tuition helping to put students at ease and promote a safe work environment. A CDIO centred module also doubles as an opportunity for technicians to expand their skill set and gain teaching experience. This parallel track both delivers high quality CDIO based education to students while investing in future delivery of these courses through enhancing the teaching skills of the staff involved.

CASE STUDY – MANUFACTURING TECHNOLOGY MODULE

The School of Mechanical and Aerospace Engineering at Queen's University Belfast have a variety of technical staff involved in delivering both research and education. This paper will examine a case study of the Manufacturing Technology module as both a CDIO module for students and a CDIO learning context for teacher training of technical staff. A previous paper by Cairns et al. focused on the development of this module and how it impacted the student experience and their feedback. The focus here will shift to the parallel benefits of how CDIO modules provide technical staff with teacher training and experience through their delivery.

Module Overview

Manufacturing Technology 2 is a second-year undergraduate module for all students within the school, delivered over one semester. As detailed by Cairns et al., (2024) the school boasts a wide range of manufacturing technologies and processes with highly experienced technical staff. Capabilities include Laser Cutting, Hot Wire Cutting, 3D Printing, CNC machining, Lathe turning, a robot platform and various Composite and Polymer Processes (Cairns, Millen, Pick, & McCartan, 2024). The aim of the module was to create an artefact (*Figure 1*) which could be assessed and students would keep, which included a variety of manufacturing processes that students could both observe and experience hands on (*Figure 2* & *Figure 3*). As the practical workshops would be delivered primarily by the technical staff their input in the module design at every stage was essential.

Figure 1: Finished Artefact

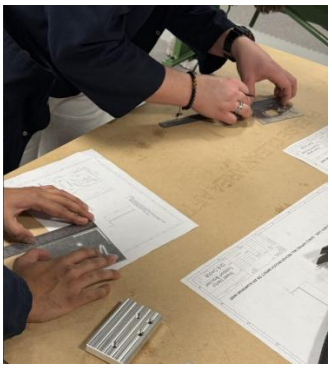

Figure 2: Students reading drawings for using hand tools

Figure 3: Students learning machining of parts in workshop

Complimentary learning material was provided during lecture sessions to both prepare the students and reinforce the learnings of the hands-on elements of the module. In the first year of the module 172 students were enrolled, these numbers have subsequently increased each year with no change in staff numbers. Students are divided into groups of five or six and scheduled to pass through five technician led workshops and demonstrations, along with two sessions of hand tool-based tasks.

Assessment is carried out once assembly has been completed. All parts must be present and working on the artefact. Assessment has been improved by observations by technical staff of common mistakes and incorporating elements to catch these errors. If parts get broken or are not manufactured correctly by the student they are given replacement parts which are a different colour to the original to make it clear to the final assessor that this has occurred and marks are deducted. This is made clear at the start of the module and motivates students to take their time and double check measurements and drawings.

The practical element of the module was conceived and designed by the senior technical staff in the school. This involved the design of the artefact and all its individual parts along with the breakdown of the technical knowledge that would be communicated during the sessions. Technicians with particular specialisms reviewed the lecture content for that part of the module to ensure cohesion with the knowledge and skill communicated in the practical session. This enabled a parallel CDIO path for both students and technicians through the module.

CDIO parallel track

Table 2 illustrates the parallel path students and technicians take through Conceive – Design – Implement – Operate gaining their respective outcomes in the process.

Surveys and Data

Vevox surveys are carried out each year with the students on their experience of this module. In addition, a short survey was completed by eleven technical staff in the 2025/26 academic year, on their perspective and experience of delivering the module. The technical staff who took part comprise of 4 education technicians, who work directly with students for both delivery of modules, support for final year projects and lab training, and 7 workshop technicians who run the in-house workshop manufacturing parts for all student project and research work done within the university alongside supporting practical modules. Most of these technical staff had delivered the module for three years consecutively. Technical staff were asked to rate the importance of engineering students learning hands on skills from experienced practitioners and the importance of their involvement in the design of the module. Staff were also asked several questions requiring a comment.

RESULTS

Both questions relating to the importance of students learning hands on skills and the importance of technician involvement in module design were rated very important by majority of staff (*Figure 4*).

A selection of comments from the open response questions are shown in *Table 3*

None of the technical staff delivering the module received any formal teacher training or were assessed on how they delivered their section of the module and so were under no obligation to make any adjustments to their delivery. However, when asked if they were making changes to improve the delivery of the module the answer was yes across the board. The comments illustrate how continual improvements are being carried out organically by each staff member, indicating an innate reflective approach to their own teaching practice. When asked if delivering the module was valuable for their professional development, the comments were very positive illustrating their interest and enjoyment in transferring their knowledge and skill directly to students despite no formal recognition of the teaching skills they are developing through this process.

Table 2 CDIO parallel track (Power, Tanner, Ryan, & Devitt, 2019) (Bui, Nguyen, Nguyen, & Nguyen, 2025)

	Student	Technical Staff
Conceive	Lectures on what the practical element of the module will involve and how students should approach each stage along with the theory behind the equipment	Stakeholder in conception of the module with a leading role in conception of practical elements and its assessment
Design	Create CAD for parts of the artefact. Learn how to read and understand drawings	Design of the artefact including decisions on what is possible, time involved in completing each stage, detailed descriptions of the learning objectives of each stage set out by senior technical staff
Implement	Making the parts, using hand tools, 3D printing, learning and observing how the machined parts are made.	Setting up the resources. Supplies and consumables for equipment. Determining staffing needs. Varied training to allow for cover of other staff. Providing PPE and health and safety talks. Setting out workshop and hand tool processes.
Operate	Assembly of final piece – understanding the importance of each stage and how each part is dependent on another to fit together for a finished piece.	Delivering the module. Managing the number of students. Module spread across number of locations and areas, technicians managing each space and health and safety.
Outcome	Gain practical skills and understanding in engineering learning directly from practitioners, contributes to more "employment ready" engineering graduates	Gain practical skills and understanding in teaching through delivering the modules and working through each stage of development with the academics. Opportunity to design the module, gain an understanding of factoring in assessment when designing the artefact, practical teaching skills of communicating detailed technical knowledge directly to students, adapting teaching style for each group and improving each year.

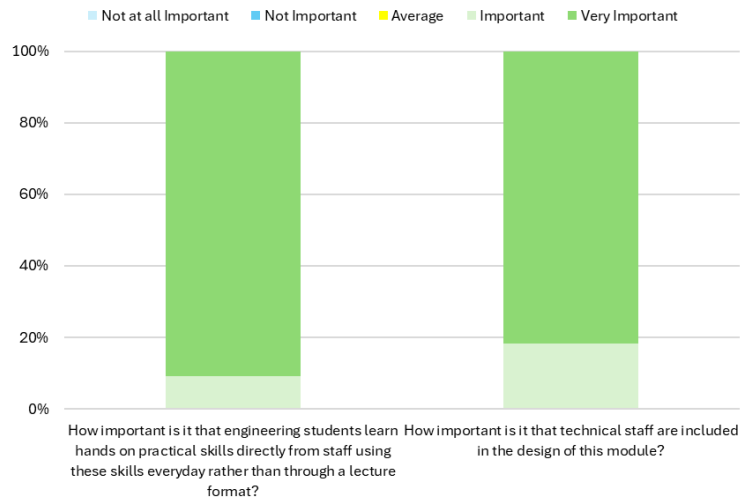

Figure 4 Technical Staff survey results

The benefits of being involved in teaching for technical staff from a career pathway point of view are unclear. Without formal recognition of this element of their work it is not a visible skill that is accounted for in career progression and pay scales. The appetite for more practical modules is clear in the final question illustrating the potential for extending the current CDIO offerings within the syllabus by utilising the expertise and teaching skills of technical staff.

Table 3: Staff survey comments

Have you made changes or improvements to how you deliver the module over the last three years based on what you have learned?	*"Yes, while delivering the theory parts of the lesson I have tried to introduce **structured opportunities** for students to **engage** via group participation in answers questions / brainstorming improvements. I find this helps **maintain interest** in the subject. We have also adjusted how the class is structured each year to improve the student experience."* *"Yes we have continually developed both the content of the module and the approach taken to deliver it; from a time point of view moving from a **structured format to a push/pull** that allows students to work on the elements within the technical lab continually through the class rather than being stuck waiting at a station waiting for others. We have increased the amount of equipment available, added additional processes and **improved the knowledge transfer between staff and students** by fine tuning dialogue to **improve the student learning outcomes/experience**."* *"Yes. Explaining more about the importance in manufacturing safety. The difference between a 3 Axis & 5 Axis milling machine, explaining their capabilities. **What an employer would be looking for** in manufacturing. The importance of designs & drawing using general tolerancing to keep the components cost effective"*
Do you think the opportunity to teach directly to students is valuable to your professional development?	*"I think its valuable to your **personal development**. Professional development, I'm unsure due to limitations within the University for technical staff progression"* *"Yes. Every year the students will ask a wide range of questions, some of which **I won't have considered before and need to seek out the answer to provide them**. Through this process **we all learn a bit more** and I am better placed to provide that information to the next group"* *"Yes, it helps **build rapport** with the students and also with other members of staff who are involved in the module."*
Would you be open to technical staff delivering more practical modules?	*"Yes, technical staff have the technical and practical expertise that would help improve the students experience and knowledge. Engaged students would definitely benefit from more practical classes as I know they enjoy this part of the degree."* *"Yes I would as I really enjoy the interaction with the students, I also think the students really benefit from the technicians one to one experience"*

The overall goal of the implementation of CDIO modules is to improve student engagement, experience and produce graduates ready for industry. These goals are reflected in the student data from the last three years of running this module. One example is that attendance has improved year upon as shown in *Figure 5* with well above 90% attendance in all practicals for the last 2 years. While improved attendance cannot be directly attributed to the CDIO

approach within the module alone. Additional student survey results from the module's first year as stated in Cairns et al., where students were asked open ended questions are shown in Table 4 indicating very positive student experiences of the practical elements of this module.

Table 4: Selected comments on module content and perception

How did you find the practical classes?	*"[It was] good to see all practical elements in person. The CNC practical was a lot of standing - too much information for the time spent. Technician support throughout was great."* *"I very much enjoyed the practical sessions – I did Technology and Design at school and missed the practical side in first year Aerospace. Seeing the workshop was great."*
How did you find the lecture material?	*"Very good lecture content with good links to our Design and Manufacturing module. Despite a couple of repeated lectures, I took different things from each."* *"[The] lecture content was interesting – clear layout and diagrams, One mechanical and one aero example would have been good."*
Did you feel you were learning when completing the practical classes?	*"Yes – more so when actually doing and when practicals complimented each other"* *"Yes – in some more than others. I don't feel I learned as much when only observing."*
How did you find the module overall?	*"Manufacturing Technology has been my favourite subject this year. I really enjoyed making the artefact and enjoyed [the] lectures. I appreciated how the subject could be applied to industry."* *"Happy overall with module - a good break from the theory heavy modules. I really like having the artefact on my desk and play with it when working."*

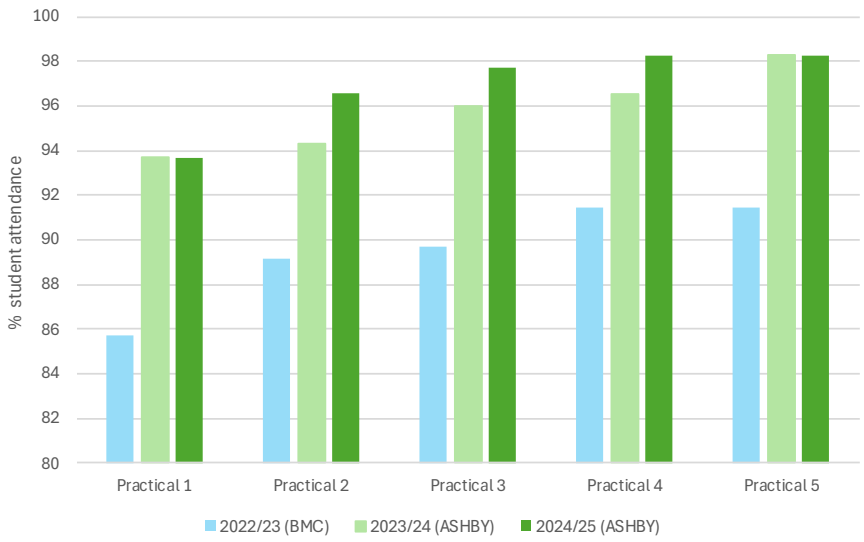

Figure 5: Student attendance for each practical for three consecutive years

CONCLUSIONS

The data and observations herein have shown that technicians are undergoing invisible teacher training in a CDIO learning context. If this could be formally recognised and utilised, it could provide engineering faculties with more experienced trained staff to expand on their delivery of the CDIO approach and benefit student learning. Improving CDIO modules to help students acquire disciplinary knowledge as well as personal and inter personal skills. This will increase their compliance with CDIO Standards 7, 9 & 10 and aid in facing down the challenge of increasing student numbers and lower academic staff to student ratios. In addition, this could provide potential professional development channels for technical staff that don't currently exist, giving more opportunities and recognised transferable skills. Most importantly extending a university's ability to offer CDIO modules will improve both the student experience

and the graduates produced. Addressing the very fundamentals of the CDIO approach to produce ‘employment ready’ graduates. Further to this, when the university values technical skills and knowledge they lead by example to produce graduates who do, ensuring respect, awareness and practical foundations in the many varied and complex skills that are involved in research, education and industry in the field of engineering.

LIMITATIONS

The published research exploring the role of technicians is limited. However, within the literature there is clear evidence of the importance of their contribution to both education and research and the need for it to be valued, visible and recognised. The above data is limited by number of technicians who took part in the survey, and is confined a single institution. Only attendance data for students was taken over multiple years. It would be beneficial to rerun the original survey from the inception of the module again now for comparison. Attendance data alone cannot be directly linked to a positive student experience in the module.

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Charles McCartan is a Reader in the School of Mechanical and Aerospace Engineering at Queen's University Belfast. His research centres on curriculum innovation, active learning, and student transition, with expertise in CDIO-based approaches and authentic, project-driven experiences. He contributes to frameworks for agile, future-ready programmes and strategies that enhance engagement and retention through flexible pedagogy and curriculum design.

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Jonathan Preshaw holds a BEng Hons Degree in Mechanical Engineering and is a Engineering Technician at QUB. He has over 10 years manufacturing experience with specific expertise in NDT, materials characterisation and process quality. Jonathan was a key player in the development of the practical aspect of the ManTech module and continues to be involved in the delivery of this part of the module alongside the technical team in QUB.

Adam Richmond is a Manufacturing Technician at Queen's University Belfast with experience in various sectors including oil & gas, aerospace and defence industries. His expertise is in the design and manufacture of precision components, utilising CNC machinery and CAD/CAM software's to support teaching, student projects and research.

Robert Vaughan is a Lead Manufacturing Technician at QUB. Robert is a time served Precision engineer with over 36 years' experience in machining and programming. Throughout his career in industry, he covered a wide variety of sectors including Aerospace, food & automotive engineering to name but a few. He is currently supporting manufacturing within the QUB Workshop utilising 5 axis-controlled machinery and CAD CAM software.

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