2.2

Process Management on a Process Level

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Project management is a key engineering skill, which encompasses several technical and transferable skills and competencies, necessary to ensure the successful completion of complex engineering projects. In this chapter, a definition and a brief history of project management is provided, and some reflections on its importance for engineers are offered. Then, a practical example is described that shows how to help students to develop the set of skills embedded in project management: a programme designed within a Joint Education Institute by Queen Mary University of London Engineering School at Northwestern Polytechnical University in Xi'an, China. Students at this university undertake Professional Engineering Skills (PES) modules during the first three years of study, which are designed to support students to develop academic, professional, and employability skills. The example shows the importance of a progressive and developmental approach to project management to ensure student success. Finally, the chapter discusses some considerations and lessons learned about teaching project management to engineers.

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1 Definition

The work of engineers is increasingly described and organised in terms of "projects", whatever their specialisation: goal orientation, problem solving, and time and resource constraints characterise engineering activities. That is why project management has become such an important discipline for engineers.

Defining project management implies, first, the definition of what a project is. Many definitions of a project can be appropriate, depending on the perspective and reference context (Bredillet, 2007; 2008; Kolliveit et al., 2007):

- Planning perspective: the project as a set of activities to be completed within a certain time, with a defined number of resources;
- Organisational perspective: the project as a set of resources that need to be organised to realise the project's objectives;
- System perspective: the project as a set of sub-systems, dynamically interacting with each other, letting problems, conflicts and solutions emerge from that interaction.

A possible integrated definition, which considers all the perspectives above, could see the project as a process in which human, material and financial resources are organised in a new way to achieve a unique output within defined time and cost constraints (Buganza & Kalchschmidt, 2022; Turner, 1999).

Managing projects is not trivial, as has been known since ancient times. An excellent example is Vitruvius' work *On Architecture*, dating to the first century BCE, which describes in detail the technical and organisational aspects in the construction of aqueducts. But it was only in the 20th century that project management moved beyond the 'artisanal' dimension and became a technical discipline, with a solid theoretical background complementing the practical experience. Henry Gantt was probably one of the first authors designing tools for supporting the organisation and management of engineering projects. Following Gantt and the world-famous Gantt Chart, several other authors in the first half of the 20th century developed tools such as the Critical Path Method (CPM) and the Program Evaluation Review Technique (PERT) for scheduling activities. Since then, project management has been conceived mainly as a discipline focused on planning activities and plan optimisation. Later in the 20th century, aspects more related to project organisation, costs, and expected revenues have been considered, for example in the Work Breakdown Structure for eliciting the activities necessary to achieve the project scope, and the Earned Value techniques, for measuring the economic impact.

In 1969 an important organisation was established, the Project Management Institute (PMI), a community working to support managers in developing, improving, and sharing tools for increasing the probability of projects success. With the establishment and the growth of the PMI, project management has been recognised as a discipline, and the project manager established as a professional role. Since then, the discipline

has continuously evolved, increasingly including more 'soft' aspects concerning the cultural, human, and social side of project management. The aspect of the *impact* generated by engineering projects has also emerged as fundamental: the PMI's current vision is indeed building "*a world where every project lives up to its full potential for positive impact"* (PMI, 2026, front matter). Project management has thus become a discipline which is aimed not only at ensuring the project's success but also making sure that projects generate economic and social value.

Following the Project Management Book of Knowledge (PMBoK) published by the PMI we use the following definition of project management: *"the application of knowledge, skills, tools and techniques to project activities to meet the project requirements"* (PMI, 2026, p. 4). The PMBoK illustrates and discusses the most important technical tools for project management and their application in various contexts. But human skills and competencies have a dramatic impact on the success of projects (Rezvani et al., 2018; Pant & Barouni, 2008; Stevenson & Starweather, 2010). Among them are social skills — defined as "*a person's ability to understand, socially interact, control, read effectively to fulfil an objective or a specific goal"* (Zaman et al., 2019, p. 446) — , communication skills, teamwork, leadership, adaptability, and verbal and written reporting skills. So, being good project manager is a matter of integrating technical skills with human and social skills. Not an easy task, but one of which you should be fully aware.

2 Why teach project management?

It is widely recognised that engineering work is predominantly organised through projects. Consequently, the ability to manage projects successfully is crucial for engineers. Engineers are required to have a number of technical skills, as well as transferable skills and competencies to be considered competent in their profession (Engineering Council, 2020). However, it is widely reported that engineers lack transferable skills and competencies. The Employer Skills Survey cites that 51% of engineers lack time management and task prioritisation skills (Winterbotham et al., 2018), even though these are key skills in project management. In the end, this has a negative effect on the profit of businesses (IET, 2021). The same is indicated by accreditation bodies and frameworks, such as the UK AHEP4 and the related EUR-ACE Accord (EUR-ACE), Washington Accord (WA), Sydney Accord (SA), and Dublin Accord (DA). Indeed, they explicitly mention engineering and project management among the areas of learning that are expected from bachelor- and master-level engineers. The Global Competitiveness Report 2020 (WEF, 2020) discusses the need for educators to ensure students leave education with 'job-ready skills' for the future job markets, especially for recovery after the COVID-19 pandemic. Therefore, it is a university's responsibility to ensure students develop the skills needed during their studies (Department of Education, 2017) in an inclusive manner, using innovative pedagogies. Additionally, for engineering education institutions to be accredited, the capacity to bring into their regular curricula all the necessary transferable skills and

competencies to make engineers successful including the ability to apply the principles of project management is key.

Moreover, successful project management is becoming increasingly challenging due to budget constraints, time pressures, and rising levels of risk and cost (Stevenson & Starkweather, 2010). This underscores the need for engineers, and, more importantly, for engineering educators, to integrate the necessary skills and competencies that enhance the probability of project success into the curriculum. We cannot expect that students are able to perform at the level of a project manager, especially at a first-year undergraduate level, so project management should be taught in a progressive manner.

2.1 Intrinsic characteristics of engineering projects

But why is managing such projects so difficult? The discipline of project management can be described as "*a multifaceted discipline that involves planning, executing and completing projects of all sizes and complexities"* (APMG International, 2023). The increasing complexity of project management stems from a range of factors, some intrinsic to the nature of projects, others related to the broader contextual environment in which these projects take place. The following characteristics, inherent to engineering projects, contribute to their complexity:

- *Uniqueness of outputs and activities.* Each project typically delivers a unique output through non-standardised activities, limiting the applicability of established processes, routines, and procedures;
- *Temporary nature.* Projects have defined start and end dates, requiring the creation of a dedicated temporary organisational structure with appropriate allocation of resources and competences;
- *Need for new competencies.* Achieving novel or innovative outputs may demand skills that are not readily available within the organisation and must therefore be acquired externally or developed internally;
- *High interdependence.* Projects often involve complex interrelations between their various components, requiring integrated planning and coordination;
- *Goal orientation.* Specific project goals need to be identified and codified, requiring iterative definition and alignment within the organisation.

2.2 Contextual complexity

Beyond their intrinsic features, engineering projects operate in increasingly dynamic technological, social, and economic environments. Today's projects frequently involve multiple and diverse stakeholders or 'agents', including large and small enterprises, universities and research institutions, government bodies, communities, end users, and even physical ecosystems. These agents have dynamic interactions among them, often in unpredictable ways, contributing to emergent behaviours and outcomes that cannot be easily foreseen or controlled.

As a result, project management is characterised by high levels of uncertainty, risk, and organisational and managerial complexity. In light of these challenges, the literature increasingly recognises that successful project management requires a broad and integrated set of skills, competences, and tools. These include a mix of technical, interpersonal, professional, and transversal skills, many of which are explored in other sections of this handbook and are consistently emphasised in both academic and professional sources. As highlighted by the Royal Academy of Engineering (2024) in its Engineering 2030 literature review: "*Although working with problems, creativity, and systems thinking can all be defined as individual skillsets, the way these skills come together often works as a skillset in its own right, especially when combined with project management skills. The primary examples of this are in optimisation and innovation, and the combined skillsets needed are becoming ever more prominent as technologies become more interconnected and complex"*.

Historically, project management education and practice focused predominantly on the "hard" side - the technical tools and methods at the core of the discipline. The Project Management Institute and its foundational Project Management Book of Knowledge (PMBoK) offer key references in this domain, particularly concerning technical tools and best practices validated through extensive professional application. However, recent contributions from both the scientific (Buganza et al., 2013; Pant & Baroudi, 2018; Rezvani et al., 2018; Stevenson & Starkweather, 2010; Zaman et al., 2019) and professional (RAE, 2024) communities underscore that technical skills alone are insufficient for project success.

Stevenson and Starkweather (2010), for example, identified critical project management competences in IT projects, including leadership, multi-level communication, verbal and written reporting skills, a positive attitude, and the ability to manage ambiguity and change. Similarly, Belzer (2011) referred to soft skills as the 'missing link' for successful project outcomes, emphasising competences such as communication, organisational effectiveness, leadership, problem solving, decision making, team building, flexibility, creativity, and trustworthiness. The literature increasingly emphasises that project managers must achieve project objectives through people, managing not only tasks and technical aspects but also the human, psychological, and social dimensions of project work. These dimensions are no less critical than technical proficiency to ensuring successful project completion. Therefore, there is now a broad consensus among scholars and practitioners on the necessity of integrating technical and socio-human skills in project management. This awareness must be followed by a second, equally essential step: understanding how such an integrated skill set can be effectively taught within traditional engineering curricula.

3 Forms of implementation

This section will identify a case study where project management has been implemented to develop the transferable skills and competencies of students at undergraduate level over the duration of the degree programme.

Context

Queen Mary University of London Engineering School at Northwestern Polytechnical University, in Xi'an, China, offer a Joint Education Institute (JEI) for two undergraduate programmes of study: Material Science and Engineering and Polymer Material Science and Engineering. The programme of study spans four academic years, after which students are awarded a degree from both universities.

During the first three years of study students undertake Professional Engineering Skills (PES) modules which are designed to support students to develop academic, professional, and employability skills. Each year has around 240 students in two classes of approximately 120 students each.

Level of study and progression

Fig. 2.2.1 below shows the main professional skills that we address in each of the modules throughout the programme of study.

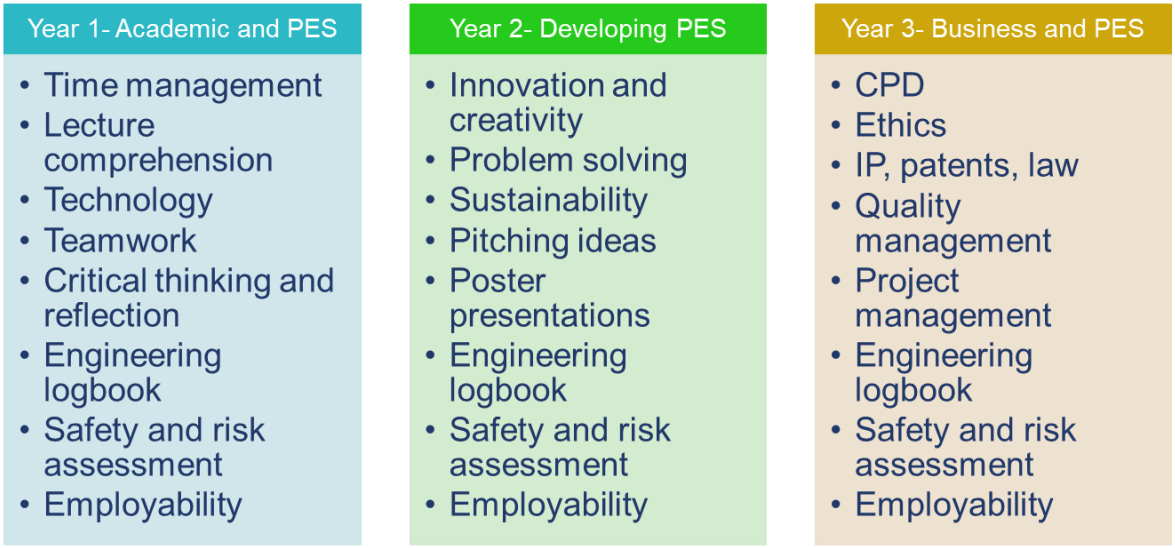

Figure 2.2.1: Professional Engineering Skills (PES) modules outline (Own Work by Faith Nightingale)

In PES1, we introduce time management and teamwork as key skills that form part of project management in terms of time and resource management. In PES2, the project-based approach introduces more developed teamwork skills and skills such as recording meeting minutes as part of student project management development. Finally, in PES3, project management is introduced at a higher level through guest lectures and use of project management tools and modules. It is vital that learning project management skills is scaffolded because there are many skills that need to be developed within project management, such as time management, teamwork, and planning and organisational skills. Additionally, context plays an important role in the scaffolding of skills. This case study shows that especially for undergraduate students

who may be unaware of project management, in this transnational setting, with two countries where the pedagogy and culture are different, scaffolding is essential.

Teaching methods

To teach project management, an interdisciplinary, project-based approach needs to be used, with real-life engineering scenarios. This method aligns with the growing emphasis in engineering education on problem and project-based learning (PjBL) as a means to prepare graduates for complex, real-world challenges (Kolmos et al., 2023; Lavado-Anguera et al., 2024). Interdisciplinary PjBL enables students to work across technical and non-technical domains, reflecting the collaborative nature of modern engineering projects. By simulating authentic engineering contexts, students engage in experiential learning that fosters critical thinking, systems thinking, and adaptability (Lavado-Anguera et al., 2024). This also aligns with the development of skills which are valued by professional engineering institutions. Lavado-Anguera et al. also note that PjBL enhances both technical competencies and transferable skills such as leadership, negotiation, and conflict resolution. By enhancing transferable skills and competencies in a real-world project using hard skills, students will develop interdisciplinary abilities and project planning and execution abilities, meeting industry demands.

There is also an opportunity to further innovate and develop additional skills, particularly technological skills. Traditional teaching methods such as lectures, case studies, and hands-on workshops remain valuable for building foundational knowledge and structured problem-solving habits. These approaches provide the conceptual grounding necessary for understanding project management frameworks. However, integrating innovative, technology-enhanced methods can significantly expand skill development. For example, collaborative platforms like Office 365 facilitate real-time teamwork across geographies, reflecting the distributed nature of modern engineering teams, even if, as in this context, the students are in the same location. It helps them develop skills for the future and use technology in case they cannot meet in person due to other commitments. Importantly, digital literacy is essential in project management. Therefore, balancing traditional and innovative pedagogical methods ensures that students not only master established project management practices, but also adapt to emerging technologies, preparing them for leadership in a rapidly evolving professional landscape (Falasi, 2024).

Practical examples

Example 1. Implementing project management skills in a programme

Year 1.

As part of a joint assessment with an English module, project management is not explicitly taught, but the skills teamwork and time management are introduced and practiced so that students are able to use key elements of project management.

For the assessment, groups of five or six students are asked to prepare a short presentation and lead a seminar on an engineering topic. Students are given several

weeks to prepare for this and are also supported with other skills such as presentation and seminar participation skills. However, project management is used in the form of writing action plans, as seen in Fig. 2.2.2.

Action Plan 1

Date:

Person responsible Who is doing the task?	**Task** Provide clear details about the task each member needs to do, including specific requirements, resources, or steps needed to complete the task.	**Submission form** E.g. word doc, PPT, URL, image, excel figure etc. on SharePoint	**DDL** Date the task should be finished.	**Task comp'd?** Not Started/ In Progress/ Completed	**Checker** Who is checking the task?	**Comments on the work** 2 positives, 2 improvements from checker

Figure 2.2.2: Action plan — Year 1 project management (Own Work by Faith Nightingale)

The action plan aids students in developing their project management skills by organising people, tasks, resources, and time, as shown in the first five columns of the table. The title of each column also includes an explanation of what information should be included, which is important to ensure that first-year students understand the requirements.

It also acts as a feedback mechanism to aid students in the development of their work. Feedback is given internally by other group members, as someone is assigned to check the work and give comments, as seen in the final two columns of the table. Giving and receiving feedback develops students' professional skills as well as replicating real-life scenarios, e.g., receiving and acting on feedback from a teacher, or in the workplace, a manager.

The action plan is assessed as part of the group project in order to assess the skills and engagement of the students. The number of action plans, use of technology, communication skills, and responsibility are all taken into account. At the JEI, students value grades highly, which is why it is important to assess these skills in a quantitative way. However, students also complete their Engineering Logbook as a way to show their professional development (Nightingale, 2022), which enables students to reflect on their performance and therefore aids in the development loop of gaining professional skills.

Year 2.

In order to develop the professional engineering skills of students, the module is completely project-based. Students complete two projects, one per semester, which are focussed on real-life engineering scenarios.

In the first semester, students complete a joint assessment in Engineering Design Methods and Developing Professional Engineering Skills. The project aims to enable students to use their creativity and innovation skills to design their own product

using features of sustainability, CAD/CAM, and market research. As an interdisciplinary, semester-long group project, project management is key to ensure the smooth running of this project.

To develop the project management skills from Year 1, students in Year 2 are required to record meeting minutes in addition to developing and following up on the action plan. Students are asked to create written minutes of the meeting and upload them to SharePoint after each meeting (which also improves their technology and software skills). Guidance in class is given via a 'meeting minutes' guide. One of the reasons for requiring students to record meeting minutes is to develop workplace skills in three areas. Firstly, arranging a meeting can be difficult for the students because of their busy timetables and the fact it is group work. Therefore, not all students are available for every meeting, so having minutes enables those who missed the meeting to catch up on what was discussed and the tasks that were decided upon.

Project Management Form Template

Your group number	
Attendance (Indicate Chair & minute taker)	
Absence	
Project and meeting number	
Date, time and place of meeting	

Discussion point/task

Action Plan

Member	Detailed action points	Submission form	DDL	Task comp'd?

Figure 2.2.3: Project management meeting minutes
(Own Work by Faith Nightingale)

Secondly, recording the assigned tasks creates accountability for the students, which is considered when reviewing the meeting minutes. It is expected that all students contribute to the project during each phase, including the meetings, so recording discussions as well as tasks is important since this ensures that each person is aware of their responsibilities and deadlines, enhancing accountability. Project engagement is also part of the marking criteria, so it is expected that each person's contribution can be tracked throughout the project. Thirdly, by being the minute taker, professional skills such as listening and communication, assertiveness, organisation, reporting skills, and critical thinking skills are developed (Lee, 2025). At the JEI, the students are expected to rotate roles, so they are able to develop a

variety of skills throughout the project. It is also important to develop all of these areas, as these are all professional skills that students will need in the future. Fig. 2.2.3 shows the meeting minutes template.

One point to notice is that the feedback loop is not included in the action plan at this time. This is because it is expected that students will continue this feedback loop themselves and discuss it in the meeting itself (as a developmental factor from Year 1). Additionally, the meeting minutes are commented on by the teacher to add another layer to the feedback loop, namely, to see if the documents are readable from an outside perspective. This is important to help the students develop the transferable skills and competencies mentioned above when learning to take meeting minutes. The project management documents are commented on during the project to enable the students to continuously develop throughout the project and are evaluated at the end. Overall, research carried out at the JEI showed that 66% of students said they developed their project management skills significantly during the project.

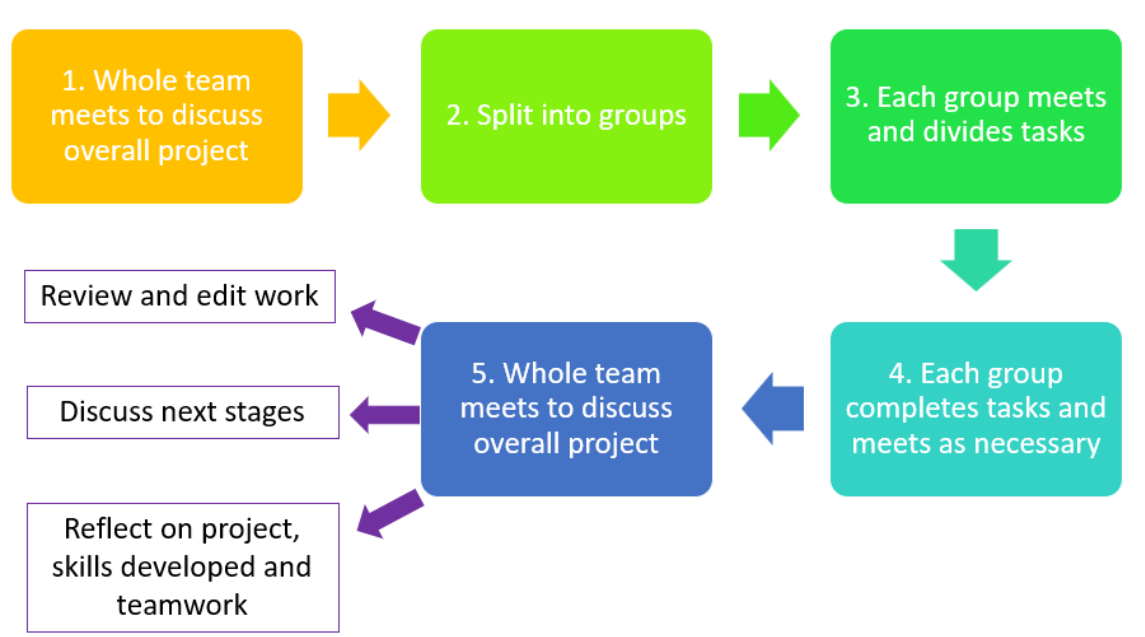

Figure 2.2.4: Project management process - team division
(Own Work by Faith Nightingale)

In the second semester, project management skills are further challenged and developed during the Materials Library project. The aim of the project is to create a database of materials or components which can be touched (where appropriate) and accessed through a website. This is done in three stages: creating a poster, creating a website, and giving a presentation. The poster is completed in pairs, and a competition is held where student peers assess the posters to choose the winners. Once the winners are chosen, large groups of eight or nine students are formed via a recruitment fair. As this is the first time that students work together in such a large group, project management is developed in two ways. Firstly, students are

advised to divide the large groups into smaller sub-groups. It is then recommended to assign a sub-team leader (usually one of the poster pair). Teamwork and leadership skills are discussed in class, and students are encouraged to follow Fig. 2.2.4, which shows the project management process in simple, easy to follow steps. This is done as students are not used to working in sub-teams, so guidance is essential. This also enables students to see stage 2 of the project overall and how to move into stage 3. During this process, students are required to still write meeting minutes each time the whole group or the sub-group meets to show the development of the Materials Library project and add these to their SharePoint group (continuing to develop the technology skills from Year 1).

The second way in which students develop their project management skills in this project is by completing a Gantt chart to aid in the planning of the project overall and the academic skills required for it, such as researching, writing, and editing. A Gantt chart is useful as it enables the entire group to see the project as a whole and understand the process of the project and the actual complexities. It also helps students set a timeframe to complete each task, as well as understand that actions can overlap. This will aid students as they aim to complete larger projects in the future, such as their final year dissertation projects.

One final step which is not directly related to project management, but an important step towards developing the skill is reflection. By reflecting on the project as well as some of the tools used in the project, they can develop this skill. For example, reflecting on the time given to each task on the Gantt chart can help students identify if they were realistic or not, and therefore, develop knowledge of timeframes and being realistic when it comes to task completion.

Year 3.

In the final year of the professional skills modules, students are expected to keep using the project management skills and tools they have developed in the first two years to complete the projects in the third.

However, in order to prepare students for the workplace and to give them an understanding of how project management is used by engineers, a guest lecturer gives the students a talk about real-world industry project management. Attending a talk by an industry professional enables the students to understand how these skills fit into their future engineering careers.

Students are also given the opportunity to use online resources from PMBoK to develop key project management understanding by looking up information on the subject, such as the project lifecycle, phases, and importantly, what is a project. This deeper understanding of project management enables students to understand when they can use the project management skills they have been developing over the past years. Students are also guided towards their final year projects by discussing leadership, communication and scheduling; all key project management skills which are needed by students as they aim to complete their degree programmes.

Challenges and solutions

The main challenge when teaching project management in engineering education is helping students to understand the importance of project management. It is difficult for students to understand that project management is a skill and combines several other professional skills to be successful. Whilst students understand the main theory behind project management, implementing it using a variety of other professional skills can be difficult. For example, communication and teamwork are skills that can be developed.

To solve this, it is important to develop students' communication and teamwork skills. This can be done as part of project-based learning, using the project management tools described above. It is also important to explain project management in an engineering context through AHEP4 and its use in professional institutions and in the workplace. Reflection on the development of project management skills after the project will also help students understand the importance of project management.

4 Recommendations for implementation and learning

Project management skills must be developed in a process that spans the entire engineering programme. As part of this progressive approach, students should first develop an awareness of the need to develop specific skills to successfully manage a project. It is necessary to gain direct experience of the complexity of engineering projects, which in turn allows students to fully appreciate the value of project management support tools. Once this awareness has been developed, students are ready to begin learning how to apply the tools, starting with the simplest ones, such as the action plan and the Gantt chart. At the end of the process, students should be given the opportunity to experiment with integrating 'hard' project management tools (action plans, Gantt charts, CPM, etc.) with other professional skills, such as communication and team management, leadership, and problem solving.

A second key recommendation is that in order to develop project management skills, these must be taught using project-based learning pedagogy. PjBL is key to putting the skill into context; teaching project management in isolation is not going to develop the skill, as students will have no place to practice it. What is important, however, is that project management skills need to be taught as part of the pedagogy. It is impossible for this skill to be developed without explicit teaching, as project management combines skills such as time management, teamwork and communication skills. Therefore, it is essential you give lessons on these skills, as well as opportunities to practice these skills.

These recommendations lead us directly to the lessons we have learned from teaching project management to engineers. Teaching project management means helping students develop many professional skills related to communication, leadership, problem solving, and managing teams (and, therefore, diversity and inclusivity, time management, and conflict resolution. This is why teaching project management is so complex and requires a progressive approach. This means that the activities (projects)

you choose to teach project management to engineers should last at least five to six weeks, to give students the opportunity to really build up their skills, both technical and professional. Projects should be open-ended and include some risks and uncertainties in order to force students to generate, evaluate, and manage multiple alternative options. This is essential for exploring and fully exploiting the potential of technical project management tools and professional skills.

The use of project management as part of skills development is highly adaptable to any context, but you need to consider two main factors: stage of the degree and culture. It is vital you consider the degree stage to ensure that the set project management skills are reachable for students. This is why project management needs to be developmental throughout the curriculum. Culture is another consideration, as the content needs to be relevant to the students and should also give room to experiment with the value of different technical or social student backgrounds.

Adaptability means that introducing project management skills in engineering curricula cannot be completely standardised, as it should be tailored according to the background knowledge of students and their cultural and social characteristics. This allows for reflecting on the value of diversity for project management and how it influences the success of projects. As shown in the practical examples at the JEI, project management can be taught to large classes (120 students), as long as an appropriate active pedagogy is used. Therefore, you can adapt the ideas above to smaller class sizes. This may yield better results, as the instructor will have more time to spend with smaller groups, and thus can ensure they are writing minutes accurately or develop an accurate Gantt chart.

Avoiding standard approaches is also consistent from the students' perspective. As already mentioned in this chapter, it is sometimes difficult to convince students of the relevance and importance of project management skills, compared to the technical skills that form the core of their engineering programme. In our experience, they can only be profitably engaged with learning project management skills if these are strongly integrated into the fundamental technical skills, which remain their focus. At the JEI, research has been conducted into the effect of teaching professional skills; one key comment from students is that project management helped them when devising and executing their final year dissertation projects. This is because this required all the professional skills they had previously learned, with a high emphasis on time and project management skills.

One way to improve the project management skills of the students is to try different project management tools, as mentioned at the beginning of this chapter. Instead of just using a Gantt chart, more emphasis could be placed on developing students' knowledge of Critical Path Analysis or Program Evaluation Review Technique. This would enable students to choose which tool to use in a particular situation, thus also aiding the students' reflection and self-development skills.

The main takeaway about project management skills is their applicability to all kinds of disciplines and contexts. One of the most surprising results for teachers is hearing students say, *'I can use these tools in my personal life too'*. This should offer motivation for us to start teaching project management skills.

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AI statement

During the preparation of this work the authors did not make use of any AI tools.

Contributor statement

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