Chapter 1
Project-Based Learning in Chemical Engineering:
Curriculum and Assessment, Culture and Learning Spaces

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ABSTRACT

Solutions to global challenges need a range of engineers with diverse skills and attributes, and it is the responsibility of engineering educators to shape the engineering education landscape, using their problem-solving expertise to educate future engineers for modern technological advances. Project-based learning (PjBL) is an educational approach that can integrate such needed skills and attributes into the curriculum. However, delivering a truly effective PjBL approach can be quite difficult without considering a holistic approach encompassing three key pillars: PjBL curriculum and assessment, PjBL culture, and physical and online PjBL spaces. This chapter presents a comprehensive overview of how PjBL has been successfully deployed across the Chemical Engineering curriculum at the University of Nottingham, UK, through the lenses of those pillars, and in the form of design projects, with a progressive integration and development of diverse skills and competencies throughout the years.

INTRODUCTION

There is no secret anymore as to why engineering schools and departments need to teach differently. Students, industries, and institutions have been demanding different learning experiences over the last decade to produce graduates with diverse skills and attributes. Whilst student demands become more focused on novel teaching methods to help them design creative solutions to global challenges and become more employable, industries demand the development of competencies that can help graduates to

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work across a multiplicity of boundaries and with people whose specialisation and cultural frameworks differ from their own (Mellors-Bourne, May, Haynes, & Talbot, 2017). On the other hand, higher education providers are demanding programmes to be designed around dynamic institutional strategies that represent the essence of their mission and values.

The most natural place in the engineering curriculum where these demands can be met and addressed is in engineering design, which is typically implemented as a standalone, capstone module or - more effectively - as the heart of the overall programme through all the course stages. In the realm of engineering, design can be defined as a "systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (Dym, Agogino, Eris, Frey, & Leifer, 2005). This process requires design teachers to look into the identification of competencies that promote expert-thinking and performance attitudes in design, and into the evaluation of how effective design courses are at developing such attributes. Adams and Atman greatly distilled the essence of design teaching as an iterative process of interpretation, selection, and planning (Adams & Atman, 1999), whereby students first access information to identify a design objective and monitor and search strategies to identify alternative options. This is then followed by an examination of the options and selection of a solution that best meets the design problem, followed by the implementation of the solution to verify that it meets the original objectives. This cyclic, non-linear iterative process reflects a natural feature of the engineer's competency (Bucciarelli, 1996) and leads to better quality solutions (Gero, 1996), offering plenty of opportunities to develop graduates who are able to value the broader socio-economic and environmental contexts, through an appreciation of sustainability, ethics, innovation and even entrepreneurship.

This chapter draws on the experiences over the past ten years in the department of chemical and environmental engineering at the University of Nottingham, UK, with the ultimate objective of providing a holistic view of how engineering students can be successfully trained for modern technological advancement through such iterative design-thinking approach. Particularly, the chapter discusses how and why diverse engineering skills and competencies are horizontally integrated through the duration of the engineering course alongside the importance of a collaborative departmental culture and suitable learning spaces.

BACKGROUND

Although embedding student, industry and institutional demands into a confined design module or programme seems to be the way forward for a sustained acquisition of professional competences, its implementation in educational practice has several challenges. Perkins developed a theory of knowledge whereby a distinction between knowledge-as-information and knowledge-as-design is made (Perkins, 2013). He claimed that in most engineering courses, knowledge is conveyed as information, relying on standard textbook problems and exercises that do not capture the broad pool of skills leading to expert-thinking of the discipline. This traditional approach to knowledge-as-information leads to the view that students cannot think or do engineering unless they know a lot of engineering, unlike the concept of knowledge-as-design, which is active and purposive, with students being able to break away from familiar frames of reference. Engineering design practised by professional engineers is eminently built upon knowledge-as-design and views the pieces of acquired knowledge as the foundational structures to

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