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Proposed vertical integration of prior learning to support students undertaking Chemical Engineering Design

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ABSTRACT

During academic session 2008–2009, the Department of Chemical Engineering, University of Strathclyde, changed Year 4 Chemical Engineering Design project teaching to include mixed groups from Bachelors and Masters programmes; team delivery and two separate components of design. This paper presents data for 408 students studying Chemical Engineering at the University of Strathclyde pre and post change; exploring the impact of these changes and highlighting potential for supported, vertically integrated learning programmes, across the first four years of teaching, to provide a framework fostering student confidence and autonomy. The impact of course restructuring indicates that Bachelors students' aspirations are increased, with no detriment to Masters performance. Early years performance over this period is unchanged, allowing separate investigation of the changes made in 2008–2009. Gender basis analysis shows that male students' performance is little affected, although the whole cohort fit shows a marked change due to the improved performance of low attaining female students. Post 2009 final performance shows direct correlation with Chemical Engineering Design mark, suggesting the latter may indicate final expected grades for given students. The study reveals widely applicable benefits for increased student motivation, managing expectation, and facilitating students' utilisation and integration of knowledge gained during their studies.

Keywords: Vertically integrated learning; Design; Teamwork development; Chemical Engineering; Problem based learning; Personal development

1. Introduction

Chemical Engineering (CE) is a sub-discipline of engineering that focuses on designing, constructing, implementing, operating and managing process plants and systems. As a result, the curriculum for CE degrees teaches students a wide range of knowledge and skills to be able to undertake this variety of tasks, including classes on core concepts and fundamentals, with incorporation of specialist material in the later years of the course. Students study core classes in heat transfer, fluid flow, thermodynamics, process analysis, reactors and process design, as well as department specific classes, such as statistics, particle technology, emerging technologies and communication. This means that the curriculum is broad yet intense and students' development is supported with myriad teaching and assessment modes, which supports the strategy of increasing student engagement (Ramsden, 2003) and enhancing subsequent performance (Gibbs and Simpson, 2004–2005) through diverse modes of assessment. The knowledge and learning gained in Years 1–4 is utilised in the capstone project of Chemical Engineering Design (CED), which is a requirement for accreditation of a CE degree course.

The focus of this paper is on exploring the impact of recent changes, made in 2009, to curriculum and course structure in relation to the CED class. These changes primarily targeted delivery and the student experience, seeking to engage, challenge, and educate students with a varied, research-informed curriculum structured so as to provide students with valuable, industry-relevant experience using a vertically integrated, problem-based course structure. The evaluative research undertaken reveals widely applicable benefits for increasing student motivation, managing expectation, and

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facilitating students' utilisation and integration of knowledge gained over the full course of their study.

The paper also highlights the challenges encountered in trying to develop methods for enhancing the performance of lower achieving students, while meeting the expectations and maintaining standards for higher achievers. These challenges are far from unique and this paper seeks to further discuss and address issues in both pedagogy and effective student learning. The study presented here demonstrates the potential of supported, vertically integrated programmes to provide a framework for high quality, high impact learning experiences that better foster confidence and autonomy, help students to appreciate their own learning, and prepare them for real world situations.

2. Background

2.1. *Chemical Engineering at the University of Strathclyde*

Although only chartered since 1964, the University of Strathclyde (UoS), and Department of Chemical and Process Engineering (CPE), can trace its CE roots back to the Andersonian Institution and the introduction of a CE course in 1888 (Schaschke, 2011). The CE course has increased its applications input by 70% in the past decade and admissions are up by 40% since 2005. The entry requirements have been increased in recent years, to AAAAB for Highers and AAA for 'A' levels, with mandatory qualifications in physics, chemistry and mathematics; there are few cases where exceptions are made to these requirements. As a consequence, the Department now admits cohorts of students with high attainment levels and aims to provide a challenging and varied educational experience for these candidates.

As a Scottish Institution, the University of Strathclyde generally offers degree programmes in line with other HE centres in Scotland, with 4-year Bachelor degrees and 5-year integrated Masters degrees. The majority of students enter University directly from Years 5 or 6 of High School in Scotland, hence, they are typically 17–18 years of age when beginning their degree programmes. Within CE at UoS, the student cohort is primarily composed of Scottish students, the greater proportion of which originate from the West Coast, and North East of Scotland. The Department offers a range of full-time degree courses, comprising the qualifications of BEng Chemical Engineering, MEng Chemical Engineering and MSci Applied Chemistry and Chemical Engineering, jointly run with, but administered by, Pure and Applied Chemistry. All three degrees are accredited by the Institution of Chemical Engineers (IChemE), and the MSci is jointly accredited by the Royal Society of Chemistry (RSC).

The CE degree at UoS was rated the best in Scotland and is a strong competitor within the UK; as a highly industry facing department, with a number of long-standing industrial contacts, there are myriad opportunities for students to engage with potential employers and gain valuable, relevant experience. Many companies specifically target CE graduates for job opportunities, placing some emphasis on preparation of students with key skills for improved sector employability. The average graduate starting salary is in the region of £28k (Institution of Chemical Engineers, 2010) and many students aim to gain chartered status (CEng) as soon as possible after graduation, as this can have salary implications of up to £5k per annum. Thus, it is often these high salary levels and the opportunity to gain chartered status that appeal to prospective students when applying for their first degree, and these often remain the key drivers for employment upon graduation.

Since 2008 CPE, and UoS, have made significant strategic investment in staff, appointing seven new academic staff, with several other colleagues recruited in the five year period prior to that time; this has caused a substantial shift in department dynamics and teaching delivery, in conjunction with a burgeoning aim of the Department to become increasingly research oriented. As a result, teaching is increasingly research informed and some classes are delivered in teams to reduce individual burden.

2.2. *Chemical Engineering Design*

2.2.1. *Course development*

Following the inception of CE as a discipline in its own right, towards the end of the 19th century, design has been an integral part of CE studies. The syllabus for Glasgow and the West of Scotland Technical College, from 1888, describes a requirement for the construction and use of chemical plant in addition to core classes (Schaschke, 2011).

As part of all accredited CE degrees within the UK, students are expected to complete a CED project towards the culmination of their studies, as part of their professional training. Completion of the CED project allows students to apply for chartered status (CEng) from IChemE, upon graduation and attainment of a minimum period of professional experience. At UoS, failure to complete the CED project results in the non-award of honours status with the degree classification, and an extended period of proof, from relevant experience and additional study, to gain chartered status. Hence the CED project is viewed as highly desirable by students and industry alike.

CPE offers both a Bachelors of Engineering (BEng) degree programme over 4 years and a Masters of Engineering (MEng) CE degree programme, over 5 years; both programmes offer the same curricula in Years 1 through 4, with courses in CE core concepts and applied fields. The MEng degree is an integrated Masters, where students attaining a minimum level of achievement, currently 60%, can choose to study Masters level material in a fifth year of study and graduate with an MEng qualification. Students studying for the combined Masters of Science (MSci) degree in CE and applied chemistry are registered with the Department of Pure and Applied Chemistry but half of their annual curriculum is delivered by the CE Department. Consequently, all three cohorts are registered for class 18,475: Chemical Engineering Design, as a core class in Year 4 of study. Within this class, students undertake two projects: detailed design and conceptual design, working in teams of six students, drawn from the amalgamated cohort. The design project is the capstone project within the first four years of all three degree courses and represents the application of knowledge acquired to that point.

The two Year 4 classes build upon a more structured 20 credit class in Year 3: Plant and Process Design (CP306), where students develop their thinking in relation to producing a design for a process; within this class the students receive significant tutoring and support, and it is a much less involved and less independent process than in Year 4. Many students experience theoretical difficulties with design, even in Year 3, which is partly attributable to the lack of engagement with key concepts in core classes and also related to the fact that there