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Upskilling student engineers: The role of design in meeting employers' needs

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ABSTRACT

Integrated learning makes use of group work to develop students' professional competencies in tandem with their transferable skills. This paper looks at the skills required to undertake a fourth year chemical engineering "capstone design project" (*Design*) and the skills developed therein. Staff and students were surveyed about their perceived skills abilities, both before and after the project; the results of which showed agreement as to the skills necessary to undertake *Design:* these were grouped under personal effectiveness skills, communication skills or research skills. Students described a number of extra-curricular activities that contributed to skills development but sometimes failed to appreciate their transference to academic arenas. The surveyed students indicated that their confidence in all skills areas was increased by *Design:* but there were instances where some individual sub-set devaluing occurred. There is a link between experiential practice, predominantly as a result of producing assessed components, and high skills confidence; hence, it is recommended that students are encouraged to reflect on their project experience and that integrated learning be promoted to develop all skills effectively.

1. Introduction

1.1. Skills development in chemical engineering degree cohorts

UK Higher Education has seen an enormous increase in interest in chemical engineering degrees; in 2015, there was a record 3775 enrolments on chemical, process and energy engineering courses across the UK, compared to just 750 in 2007 (UCAS, 2015). Many institutions have increased their entry grades, in alignment with higher demand, and there has been a move towards greater gender population balance. It is imperative that these well-qualified cohorts are provided with a high quality, inclusive education, which both challenges them to their full potential and attains industrial and postgraduate standards, so equipping students to enter the workplace, or further education, upon graduation.

It is true of all disciplines that a professional body will accredit university courses for quality assurance, however, it should be appreciated that such accreditation processes alone may not perfectly capture the success, or otherwise, of 'latent' skills development. The global professional body of membership for chemical engineers is the Institution of Chemical Engineers (IChemE), who provide accreditation of university degree courses, as well as company training and continuing professional development courses. IChemE also awards qualifying members with chartered chemical engineer status, as well as a range of membership categories that reflect achievement and experience (IChemE, 2015). It is one of IChemE's aims to ensure that the chemical engineering workforce maintains its skill levels, by assessing institutions and chartership against their experiences of best global practice (IChemE, 2015).

IChemE's guidance focusses on a learning outcomes based approach, rather than being content-driven, and this is the general paradigm shift that has occurred across the whole of engineering education in recent years (Fitzpatrick et al., 2009). Learning outcomes focus on the student, highlighting expected skills or capabilities, but not necessarily the method or content by which it must be achieved, thereby giving academics greater flexibility in their teaching. However, it can subsequently be difficult to explain the exact subset of skills developed on particular courses for specific cohorts, while assessing some outcomes can prove challenging.

1.2. Design projects in chemical engineering

Following the inception of chemical engineering as a discipline in its own right, *Design* has been an integral part of chemical engineering studies and, as part of all accredited chemical engineering degrees within the UK, students are expected to complete a chem-

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ical engineering design project towards the culmination of their studies, as part of their professional training.

The *Design* syllabus is defined as '*the design project is organised and run the way the Institution of Chemical Engineers recommends, to cause the student to apply knowledge of chemical engineering principles to the design of a process' and 'to demonstrate creativity and critical powers in making choices and decisions in some areas of uncertainty'. With additional elements that extend the students experience of; process evaluation and selection; safety and environment; control and operability; costing and economic evaluation*'. Hence, students are expected to undertake a project that simulates the real life demands facing a chemical engineer and to utilise knowledge gained from a range of previous courses.

Successful completion of *Design* allows students to apply for prestigious (and financially rewarding) chartered status (CEng) from IChemE, upon graduation and attainment of a minimum period of professional experience. Failure to complete *Design* results in the non-award of honours status with the degree classification, and thus an extended period of proof, from relevant experience and additional study, is required to gain chartered status. Hence, *Design* is viewed as highly desirable by students and industry alike, thus it is imperative that the required skills are developed therein.

Design gives students excellent learning opportunities through common intellectual challenges, working in learning communities, collaborative project work and, importantly, experiencing 'Engineering as Engineering is done' (Kuh, 2008). As part of *Design* students have to meet with project supervisors each week to discuss progress to date and their targets for the future. At the time of survey, Design ran as two separate projects, one covering core chemical engineering principles (detailed design) and the other focussing on the aspects of innovation and validation (conceptual design). The learning outcomes place emphasis on the consideration of a process as a unified system rather than individual parts, and to undertake creative development of a process design while at the same time considering economic viability, and environmental and safety issues. Most notably, two of the specified learning outcomes are to '*appreciate the benefits and difficulties of working in a small group as well as an individual*' and '*have deployed a reasonable selection of the skills and techniques acquired during the course (such as process design, equipment design, plant design, control and more general theory) in completing a substantial and coherent piece of work*'.

Many students experience theoretical difficulties with *Design*, which is partly attributable to the lack of engagement with key concepts in core modules. Another factor is that there is often no one definitive right answer, and the supervising academics may themselves not necessarily know what the best solution would be – this is especially true for the conceptual component of the project.

It is possible that, for some students, *Design* requires the revisiting of troublesome knowledge – a consequence of not previously engaging with key concepts earlier in the course – while for others it may present a new threshold concept (Meyer and Land, 2003), namely *Design* as a process in its own right, with many students unable to overcome their issues.

1.3. Employers' perceptions of chemical engineering graduates

The Confederation of British Industry (CBI) education and skills conducts an annual survey, in 2016, they collated the views of nearly 500 employers, representing approximately 32% of the science, engineering, manufacturing, energy and water sectors with a combined workforce of ~3.2 million (Confederation of British Industry, 2016). All employers were asked to rate their satisfaction with graduates' employability skills as either '*very satisfied*', '*satisfied*' or '*not satisfied*', ranking seven key employability skills identified by CBI as valued by employers. It is notable that five of the seven key graduate employability skills have increasing levels of dissatisfaction amongst employers, while graduates' relevant work experience also scores highly in terms of employer dissatisfaction. In 2004, the World Chemical Engineering Council (WCEC) surveyed 2,158 participants from 63 countries, to investigate '*how does chemical engineering education meet the requirements of employment?*'(World Chemical Engineering Council, 2004), ranking 26 preselected skills on a Likert scale (1: very low to 5: very high) according to the respondents' perceived views of the quality of their education and the relevance of each skill to their work. One critique of using the mean deviation to rank skills is that participants may have been comparative rather than subjective in their evaluation of each skill, using other skills as comparators and skewing the expected evaluation of educational quality and work importance; this is refuted by the authors' validation that both of the perceptions considered in determining the deviation represent the changing views of work and education priorities. An interesting result of this analysis is that the mean deviation rank assigned to '*apply knowledge and basic chemical engineering fundamentals*' is 25th out of 26, compared to the World ranking of 14th; being one of only two skills from the survey to exceed the perceived employment requirement from the education perspective, indicating that the IChemE's learning outcome for students (IChemE, 2015) to be knowledgeable in '*essential facts, concept, theories and principles of chemical engineering and its underpinning mathematics and sciences*' has not only been met, but exceeded. By contrast, many of the skills identified by the survey to be highly important for employment, such as '*ability to solve problems*', '*ability to work effectively in a team*' and '*self-learning abilities*' demonstrate a competency gap (a negative mean deviation), which indicates that educational institutions are not yet sufficiently addressing the need to develop these skills in their graduates.

Grant and Dickson (2006) have also reviewed employment skills, including a thorough investigation of a range of accreditation guides, including the IChemE, and associated bodies for graduate recruitment; their resulting classification of the main transferable skills for employment are summarised as:

- Good at communicating in a variety of forms (written, oral and so on)
- Able to work well in teams
- Able to solve problems (pro-actively and with initiative)
- Numerate and IT literate
- Able to manage themselves and continue to learn

which align with the 6 skills identified as most important in employment by the WCEC (World Chemical Engineering Council, 2004), and in line with IChemE's Learning outcomes that '*graduates must possess skills such as communication, time management, team working, inter-personal, effective use of IT including information retrieval [considered] valuable in a wide range of situations*' (IChemE, 2012). Agreement also exists between the WCEC survey results (World Chemical Engineering Council, 2004) and CBI findings (Confederation of British Industry, 2016). Here, skills perceived as under-taught in universities, by current employees, are similar to those towards which employers have expressed dissatisfaction, most notably business and management skills, suggesting measures are required to promote these skills.

Thus, there is significant evidence that the most important skills for work are those that are typically considered transferrable, and significant deficiencies exist for some skills, which are recognised by both employers and employees.