Industrial retrospective analysis to progress sustainability within the chemical engineering design project at UCC

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Abstract

As universities become more interested in, and more actively engaged with sustainability, there is an increasing need to ensure that curricula evolve to address sustainable development and its myriad facets. The chemical engineering design project is a capstone exercise on the degree programme, whereby students are afforded the opportunity to apply much of their prior learning to the holistic design of a process plant. Students must demonstrate their ability not only in core engineering activities but to also in the broader implications of their work as a chemical engineer such as safety, health, ethics, environment and more recently in the area of sustainability. Minor variations to project tasks and content of the reports have been introduced over the years, environmental issues and safety being two examples. But, in essence, the way things have been done over the past four to six decades has essentially remained the same (Fletcher and Boon, 2013).

Today there is an impetus on professional designers to practice in a responsible and 'sustainable' manner, with balanced emphasis on society, economy and the environment. This is an enormous challenge as the skills needed to develop an appropriately holistic approach can be extremely complex (IChemE, 2012).

This research surveyed the opinions of practicing chemical engineers all of whom are former graduates of the Process & Chemical Engineering degree at University College Cork (UCC). As practicing chemical engineers they are all familiar with the day to day relevance and application of sustainability and its importance across various industrial sectors. As programme graduates they have all participated in a chemical engineering design project. The opinions and perspectives were scrutinised to better understand their perspective of sustainability, how they see sustainability being implemented in practice and how the design project curriculum could be developed to meet the challenges of sustainable design for current and future engineers within the context of fit-for-purpose 21st Century engineering education.

1 Introduction

Chemical engineering involves transforming raw materials into useful products in a safe and cost effective way. Chemical engineers understand how to alter the chemical, biochemical or physical state of a substance, in order to create a vast range of products. The Institution of Chemical Engineers (IChemE) describes chemical engineering as the "design, modification and operation of processes to produce everyday materials", everything from medicines to motor oil. These products require the use of valuable resources including energy, water and raw materials, and the way in which manufacturing companies operate their businesses today has a far reaching and long lasting effect. As a result, the ChE curriculum 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 the incorporation of specialist material across the latter years of the programme (Fletcher and Boon, 2013).

The role of the final year design project in educating young chemical engineers for such a diverse employment field cannot be underestimated. This is the first opportunity for novice engineers to integrate all of the learning of their degree programme into one coherent body of information.

Accredited chemical engineering programmes operate off a common platform. Students must display competence in chemical engineering design, which requires bringing together technical and other skills, the ability to define a problem and identify constraints while applying creativity and innovation. They must understand the concept of 'fitness for purpose' and the importance of delivery" (IChemE, 2012). "Fitness for purpose" in the context of twenty first Century engineering practice is intrinsically linked to sustainability. The concept of sustainability is not new and was first mentioned by the German Miner Hans Carl von Carlowitz referring to sustainable forestry in "Sylvicultura economica" in 1713 (García-Serna et al., 2007). Sustainability in this context meant cutting only as much timber as was re-growing, with forestry having to ensure that soil fertility was maintained or even increased.

The most commonly cited contemporary definition of sustainability is around the definition proposed by the Bruntland Commission (United Nations, 1987) whereby sustainable development is seen as "meeting the needs of the present without compromising the ability of future generations to meet their needs". It is clear that we have to be less profligate in our use of non-renewable resources if the planet is to be fit for future generations to live on. In addition engineering designers must also be more aware of the consequences of our activities for society at large.

Although the design project relates to real world chemical engineering challenges, industry personnel are not normally actively involved in teaching or contributing to the learning process (Fletcher and Boon, 2013). This research seeks to look back at the final year design project on the Process & Chemical Engineering programme at University College Cork over a period of some 14 years to understand how doing a design project impacted on graduate development, in particular with respect to the emerging concepts of sustainability and on where these graduates see the future of design and the relevance of sustainability.

2 Graduate Survey

In total there were 39 respondents, 66% were male and 34% female which corresponds very well with the long term average course demographic. Graduates from 1998 to 2012 were surveyed, providing a 14 years collective of retrospection. The breakdown of employment identified the vast majority of graduates being employed in large multinational corporations, which is consistent with the Irish employment market.

70% of the graduates are members of at least one professional body (13% Engineers Ireland, 46% Institution of Chemical Engineers and 11% being a member of some other body). The survey also provided a snapshot of the diversity of careers among graduates (Figure 1).

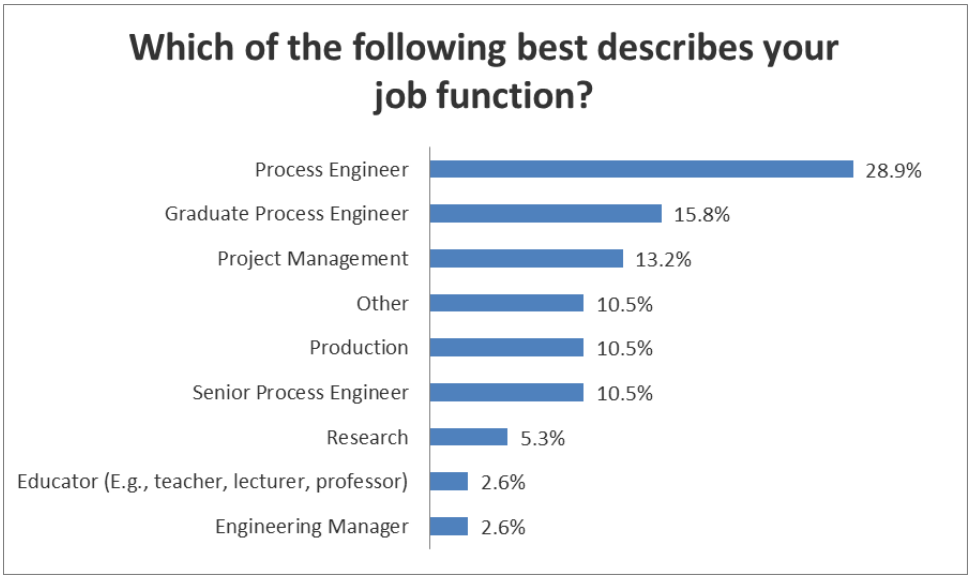

Figure 1 Graduate job descriptions

A weighted response ranking to the survey questions is used in this paper, as illustrated in figure 2, with a response of vital = 5 and Not Relevant = 1 thus in future graphs a bar indicating a weighted response of for instance 3.25 represents a collective opinion of between important and very important.

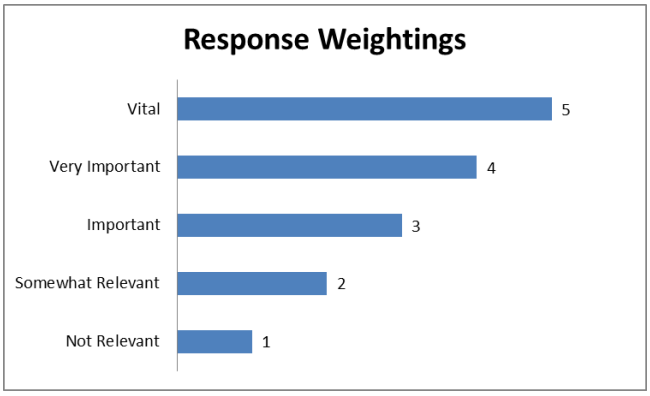

Figure 2 Survey generic response ranking

When questioned, the graduates indicated that the design project was instrumental in informing their day to day attitude across a variety of topics as shown in Figure 3. However it is interesting

to note that "social and sustainability" ranked joint lowest with an average response at around the "somewhat relevant" level among the choices offered. This perhaps reflects the fact that sustainability is still an emerging concept, and would not have featured as strongly on the graduates programme as it does on the current offering.

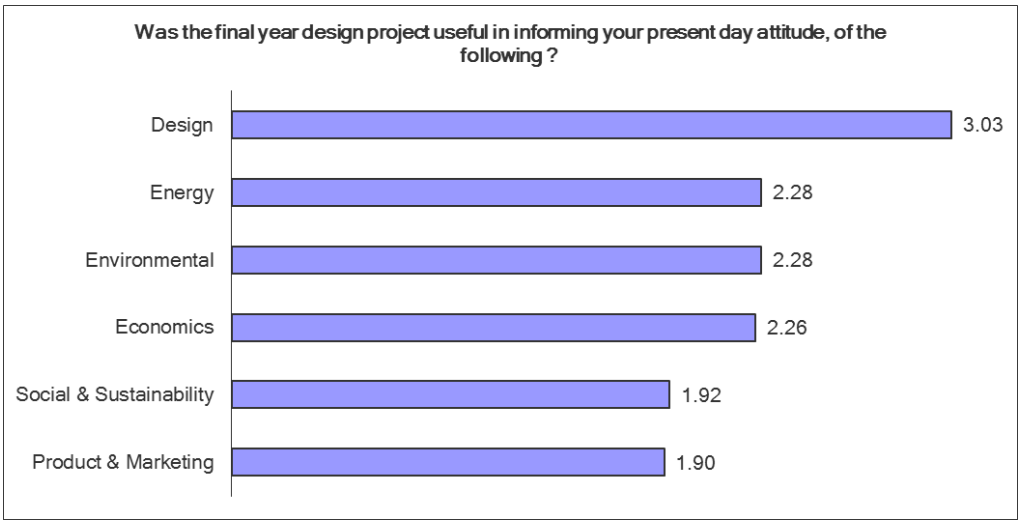

Figure 3 A breakdown of the relevance of the finaly year design project to current attitudes

Figure 4 shows the breakdown on how those surveyed considered their present day attitude to social and sustainable issues was influenced by the design project. The result is interesting; 44% of the respondents considered the design project was not relevant in informing their current attitude to social and sustainability issues while 31% of respondents considered it only somewhat important. In contrast no graduate found that the design project had a vital role in informing their attitude to these issues. In total 71% of responses indicated that the design project was not generally important in influencing their current conception. Given the relatively lower priority that these issues have commanded previously, this result is perhaps unsurprising.

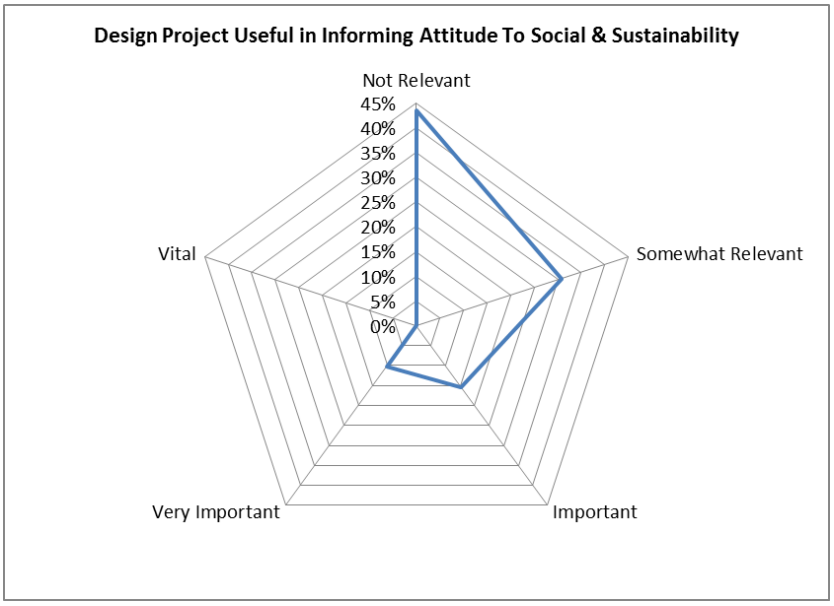

Figure 4 Breakdown of the relevance of the final year design project to current attitudes in social and sustainability

The survey also indicated the harsh reality that in many instances the notion of a responsibility towards sustainability has yet to permeate throughout industry (or among the engineering graduates working there) with one respondent stating: "My job description is simple, make sure the batch is produced according to GMP standard on time every time, how this is done and the sustainable nature of the production method is never questioned." This opinion was reflected by another respondent: "Sustainability isn't as relevant as the academic world seems to think. Of course energy reduction, green chemistry and increased sustainability are integrated into our company's corporate goals but the bottom line is that processing (e.g. yield increases) or business system improvements (e.g. automation, service outsourcing etc.) generate higher return for the company and are therefore prioritised well above sustainability initiatives". This thinking, at best the embrace of a weak sustainability untethered by social responsibility, is similar to that expressed by graduate engineers in a previous study on Australian based engineers (Dwyer and Byrne, 2010). Graduates on this study recognised issues such as "environment versus cost balance" as being far more important within industry than issues like "finding a pathway towards sustainability" or considering an "ethical framework" and overwhelmingly saw their own professional role as "agents of the client, bounded by their needs and requirements and the law" over "ethical professionals with a responsibility to society at large as well as the client". Figure 5 indicates the relative relevance of techno-economic issues in relation to sustainability that graduates would bestow on the design project. Economic and technical considerations were generally strongly favoured over sustainability.

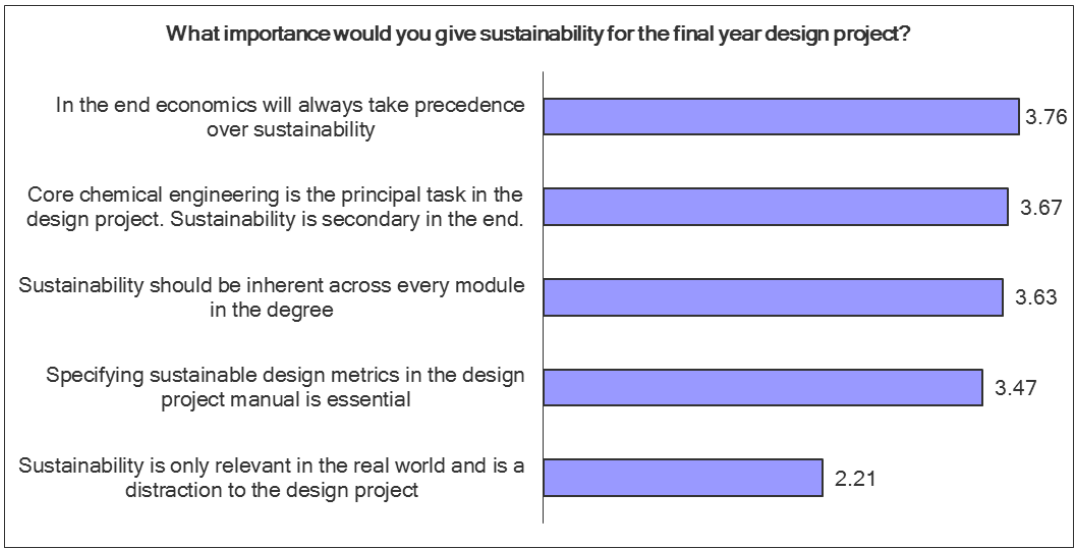

Figure 5 the role of relative role of sustainability in the FY design Project

Another question on the survey asked whether sustainability was relevant to the overall degree programme. Respondents indicated that it was an important issue that sustainability should be present across every aspect of the degree.

Figure 6 shows the relative importance graduates would place on a number of factors in assessing the design project, if they were to base it on how in their experience 'real world projects' are assessed. Clearly economics is considered close to vital (a 4.32 ranking) as might be expected from the commercially driven world. Other factors such as energy, carbon footprint, life cycle analysis and social and sustainability feature in descending order of priority.

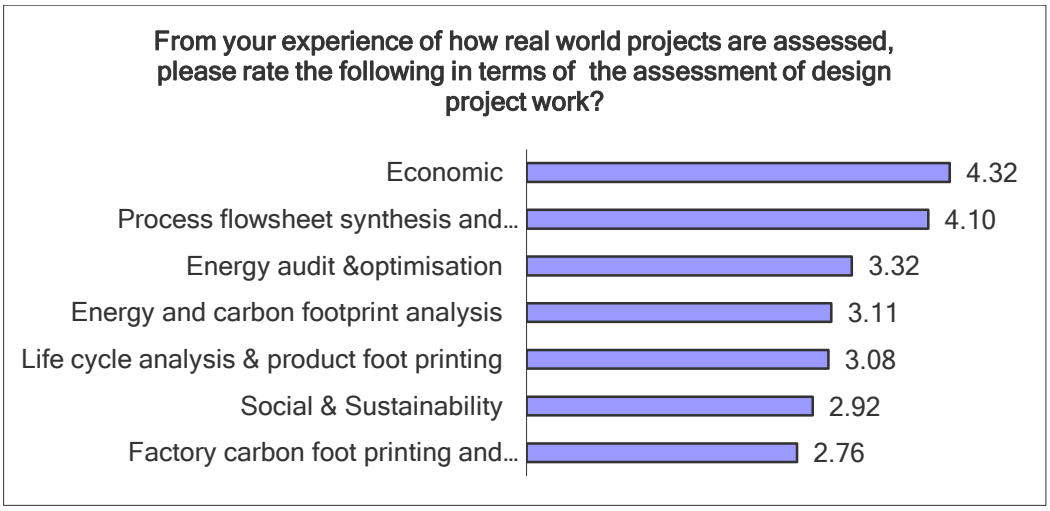

Figure 6 Relative importance of project input factors as perceived by graduates

3 Design Project: Future Scenarios

The role of engineers and designers at all scales, from molecular to global is going to be central and essential in determining how tomorrow will look. A chemical engineer, as the designer of products and processes has a central role in designing chemical processes that have a minimal impact on the environment (García-Serna et al., 2007). Figure 7 shows the preferences of graduates of the Process and Chemical Engineering degree programme at UCC in relation to the direction of the design project. Among the five options offered, "design focused on sustainability" ranks as "important. The strongest recommendations are for projects to be based on "real world industrial case studies", (considered "very important") as well as for "peer mentoring with industry based engineer", both perhaps unsurprising given the nature of the respondents' work and their corresponding worldviews. . 'Design focused on sustainability' is not considered a top priority among the graduates surveyed however This lack of concern for sustainability issues as a top priority may not be surprising given both the smaller role that sustainability played in engineering programmes in the past and given ubiquitous market drivers towards the economic bottom line. It is also consistent with current research thinking, which indicates that education often fails to equip design students with the necessary skills that allow them to practice responsibly as professionals (McMahon and Bhamra, 2012).

The typical corporate industrial approach to sustainability is exemplified by the following design template (Eli Lilly, 2012).

1. Using green chemistry and design for the environment to reduce hazardous materials use in product development and manufacturing,
2. Decreasing the environmental impact of product manufacturing
3. Reducing the environmental impact of packaging,
4. Using science-based environmental risk assessments to evaluate the potential impact of our products in the environment, and
5. Disposing of products responsibly at end-of-life.

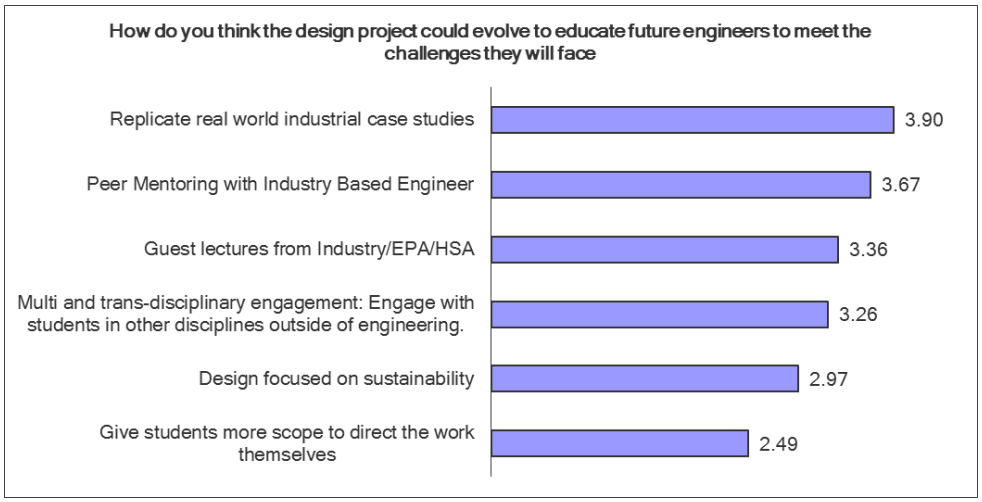

Figure 7 Industrial perspectives on the evolution of the design project

There has been an increasing interest in assessing and incorporating sustainability into the curriculum at all levels, and on how students may gain an understanding of how their decisions and actions affect the environment and society. However, questions still remain on the scope and impact of what is being taught, and the validity and reliability of curricula assessments (Lozano and Young, 2012) .

This research indicated that this gap exists also for the graduates of Process & Chemical Engineering from UCC, but some of the survey responses indicated that sustainability practices in industry are struggling also to exist meaningfully beyond corporate goals. Graduates may experience difficulty in developing and implementing sustainability principles meaningfully in industry below the corporate political world, and would like some practical guidance and/or applications. As one graduate suggested: "In many respects the sustainability we studied in college is far and beyond the sustainability practiced within industry. This is both an advantage and a disadvantage. An advantage in that we are able to contribute a lot in this area but a disadvantage in that we have studied theoretical sustainability, much of which is not achievable in reality due to economic, social and practical constraints. Although I preferred the theoretical sustainability, at the time more practical applications would be a great addition."

The teaching of sustainability across engineering courses (theoretical sustainability) has gained popularity in recent years and this can have a beneficial effect. The teaching of dedicated modules or material on sustainability may also have a positive effect on programme and professional integration and on practical implementation through the final year design project (Fletcher and Boon, 2013). In the longer terms practical and theoretical sustainability will need to find a commonality which on the one hand will drive and develop sustainability in industry, while on the other hand give form and context in education

4 Conclusions and Recommendations

The research indicates that maintaining and perhaps enhancing interaction with graduates is a potentially valuable resource in critiquing the course curriculum in particular the design project. These former students who in the final year of their study carried out a design project are in a

very interesting position being able to look back to that particular task and evaluate its relevance to industrial practice.

A key lesson of the research is that there is potentially a lot to be gained from academic and industrial professionals collaborating more fully; for mutual benefit. This work indicates an apparent mismatch in thinking with respect to sustainability between academic and industrial. But these divergent perspectives and the attendant tension between them could actually serve as a basis for mutual understanding and progress compliment given the correct platform, in this case the design project. Students could be exposed to the realities, constraints and context of the commercial world while seeking to conceptually design a process which befits a sustainability paradigm, and the pragmatic lessons learned could fortify them to enter the real world of work better equipped as "fit for purpose" 21st Century engineering graduates. The ideas, critical and independent thinking, innovation and creativity promoted through this process can thus serve the graduates in better stead than their predecessors.

Although not all real-life projects at present imply a global sustainability approach, the role of design project in a teaching programme is to teach, and so all students should be given the challenge of dealing with every crucial element of the profession, regardless of whether they will make use of it immediately after graduation or not: that will actually depend substantially on what professional career paths they will follow. It is proposed that all future design project groups will take more time than previous at the conceptual stage, with the students moving from the block design to perform the detailed design calculations only after the conceptual design has been established with a view to obtain a sustainable process. In the economic feasibility analysis of the investment, groups who wish to do so can also analyse in broad economic terms the extent to which other options might improve the immediate profitability at the expense of the long term sustainability. This implies reversing the current approach: instead of efficiency being the target and sustainability the subject of a further analysis, sustainability will be embedded in the design, and economic feasibility could be an issue for further analysis.

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