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Informing your students about the learning outcomes of your programme

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There is a global shift from solely content-driven teaching to learning outcomes driven engineering education which underpins much of the educational reform. In engineering education, degree programme learning outcomes are more commonplace as more and more professional accrediting bodies require fulfilment or compliance with prescribed learning outcomes. However, the students may not be presented with these learning outcomes as they are often "hidden" in application for accreditation documentation and not divulged to the students. This is the context of this thesis study. Undergraduate students (2006-2008) taking the BE degree programme in Process & Chemical Engineering at UCC were first surveyed to assess their level of knowledge of the learning outcomes concept and of the degree programme learning outcomes. The contents of two application documents for accreditation documents submitted to professional accreditation bodies along with Institution guidelines were reviewed to formulate the degree programme learning outcomes and these were presented to the students. These students were then surveyed after the presentation. The results of the questionnaire demonstrated a major improvement in the knowledge of the learning outcomes concept and the degree programme learning outcomes amongst the students. It also showed that the students found the session to be beneficial.

Key words: programme learning outcomes; engineering education

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1. Introduction

Learning outcomes are statements of what a student is expected to know, understand and/or be able to demonstrate after completion of a process of learning (ECTS Users'

Guide, p.47, 2005). The traditional way of designing modules and programmes was to start from the content of the course. Teachers decided on the content, planned how to teach this content and then assessed the content. This type of approach focussed on the teacher's input and on the assessment in terms of how well the students absorbed the material. This approach to teaching is commonly referred to as a teacher-centred approach. A criticism of this approach is that it can be difficult to state precisely what the student is capable of doing after passing a module or programme.

International trends in education show a shift from the "teacher-centred" approach to a "student-centred" approach (Kennedy, 2007). This alternative model focuses on what the students are expected to be able to do at the end of a module or programme. Hence, this approach is referred to as an outcomes-based approach, where learning outcomes are used to express what students are capable of doing at the end of the learning period. With the implementation of the Bologna Process by 2010, all modules and programmes throughout the participating countries must be expressed using learning outcomes.

There is a global shift from solely content-driven to outcomes driven engineering education which underpins much of the educational reform currently being undertaken by universities, government and professional organisations around the world. This began in the USA in the 1990s, where industry, government and academia gathered together to consider the future of engineering education. Academia focussed on curriculum reform but industry considered the attributes of graduate that they desired. For industry, it is important to have a broader set of attributes, in addition to technical knowledge and ability, on which the engineering schools traditionally focussed on. These attributes included communication skills, group skills, awareness of societal and global issues, ethics, professionalism and life-long learning skills. Thinking in terms of these graduate attributes shifted the attention towards what students are capable of doing (i.e. learning outcomes) as opposed to focussing purely on curriculum. This represented a major change in the philosophy of education for engineers. The interaction between industry and academia lead to the establishment of ABET Inc. (originally known as the Accreditation Board for Engineering & Technology). ABET's job was to set criteria for various engineering programmes and verify proper alignment with the criteria by the engineering colleges and schools in the U.S. (Cobb et al, 2007). In 1997, ABET

introduced *EC (Engineering Criteria) 2000*, which listed the criteria for accrediting engineering programmes (ABET, 1997). There were 8 criteria used in assessing accreditation. Criterion 3 was entitled "Program Outcomes and Assessment" which consisted of a set of learning outcomes. To satisfy criterion 3, a programme must show that these learning outcomes are being assessed and achieved by those who graduate from the programme. This was a radical shift in the method used for accreditation. In the past, the approval of new study programmes was mainly been based on input criteria, i.e., curriculum content and curricula based examination guidelines. ABET presented an outcomes-based approach to Engineering education at undergraduate level, which focused on what the students could do and what employers could expect from them. The ABET engineering criteria changes the way that programs are evaluated and thus changes the way courses are designed.

This signalled a similar shift in other countries and introduced accreditation based on outcomes rather than inputs, thereby enabling flexibility and the intention to drive innovation in engineering education. In the UK, organisations such as the Institution of Chemical Engineers (IChemE) also introduced accreditation processes based on learning outcomes including awareness of the broader contexts of engineering practice (IChemE, 2001). In the UK the actual version of IChemE's accreditation guidelines describes the minimum and distinctive core in terms of learning outcomes that a graduate from an accredited course should have acquired. In Ireland, the Institution of Engineers of Ireland introduced a learning outcomes based accreditation process in 2003 (Institution of Engineers of Ireland, 2003). They stated just six learning outcomes which are somewhat similar to those presented by ABET. The Bologna process is the major driver of the implementation of learning outcomes throughout higher education in Europe (Molzahn, 2004). It is leading to the implementation of the learning outcomes approach throughout higher education in the European Union.

In Australia, a national review of Australian Engineering Education (IEAust, 1996) called for change in the culture of engineering education (Crosthwaite et al, 2006). It reported an emphasis on technical skills and not enough cognisance of the broader role of engineering practice. In line with the review recommendations, accreditation of engineering professionals in Australia is now based on demonstrated development of

graduates with attributes reflecting these values, in other words graduates who have achieved learning outcomes.

The learning outcomes concept is spreading throughout higher education on a global basis. It is commonplace to see unit course or module descriptions containing learning outcomes which students can consider before they enrol on a course or module. In engineering education, degree programme learning outcomes are becoming more commonplace as more and more professional accrediting bodies require satisfaction of prescribed learning outcomes. However, the students may not be presented with these learning outcomes as they are often "hidden" in application for accreditation documentation and not divulged to the students. This is the context of this paper which focussed on undergraduate students in the Department of Process & Chemical Engineering in UCC. The objectives of the study were:

1. To assess the level of knowledge of learning outcomes amongst the students.
2. To "unlock" the contents of two applications for accreditation documents and formulate the degree programme learning outcomes in a format that is presentable to students.
3. To present the learning outcomes approach and the degree programme learning outcomes to the students.
4. To assess the impact of the presentation on the students.

2. Methodology

The methods used are described below in the context of each of the project objectives outlined in the introduction.

Objective 1: A questionnaire was used to assess the student knowledge of learning outcomes. The use of a questionnaire is a suitable method for achieving objective 1 because the objective is straightforward, i.e. a fact finding mission. The questionnaire was carefully constructed and reviewed by two colleagues. The questionnaire approach was an easy method to quickly survey all the students in the undergraduate programme.

Objective 2: This involved primarily documentary research and to a lesser extent by interviews with some lecturing staff. Much of this knowledge was obtained from accreditation guideline documents of the Institution of Chemical Engineers (UK) and the

Institution of Engineers Ireland, and from accreditation application documents submitted by the Department of Process & Chemical Engineering to both these institutions over the last 4 years. Once the relevant information was gathered, a document was drafted that stated the Learning outcomes of the degree programme and the structure showing which modules are striving to attain the programme learning outcomes. It also provided the students with an explanation of the learning outcomes approach, what it is, why bother with it and why is it useful to students. The draft document was reviewed by Department lecturing staff for their input.

Objective 3: A PowerPoint presentation, based on the learning outcomes document, was created and presented to first and fourth year students and the document was circulated to them at the presentation.

Objective 4: The method used to achieve this objective was to survey the students using a questionnaire. The reasons for this approach are similar to those outlined under objective 1 above. The questionnaire used was somewhat similar to that used in objective 1 where the first two questions used were also used in objective 1 and these were supplemented by additional questions to assess if the presentation session was worthwhile and to gain some additional feedback. Direct comparison with the results obtained from the student questionnaire at the beginning of the project was used to assess if there is an improvement in student knowledge of the learning outcome concept and the degree programme learning outcomes.

The qualitative data were analysed using the recommended procedure in the literature (Cohen et al., 2000; Wellington 2000) to ensure that the sample responses quoted in this paper are representative of the themes that emerged from the analysis of data.

3. Assessing the level of knowledge of learning outcomes amongst students

A questionnaire was prepared to assess the level of knowledge of learning outcomes amongst the undergraduate students in the Department of Process & Chemical Engineering. The questionnaire was designed to assess that the students had a correct understanding of the concept of learning outcomes rather than mere knowledge of the

correct definition of a learning outcome. Hence, levels of confidence (using a Likert scale) re explaining the concept of a learning outcome were used in the questionnaire rather than simply asking for knowledge of the definition of a learning outcome. Questions 2, 3 and 4 of the questionnaire are presented in Figure 1 and a summary and analysis of the student responses to these questions is provided below:

2. How would you rate your level of confidence in being able to explain the concept of a learning outcome to another person?

☐ Very confident ☐ Fairly confident ☐ Not sure ☐ Poor confidence ☐ Very poor confidence

Please comment _____

_____

3. How would you rate your level of confidence in being able to write down the Learning Outcomes of your degree programme?

☐ Very confident ☐ Fairly confident ☐ Not sure ☐ Poor confidence ☐ Very poor confidence

Please comment _____

_____

4. Has anyone in the Department explained to you what are the learning outcomes of the degree programme in Process & Chemical Engineering?

Yes ☐ No ☐

If Yes, please explain briefly _____

_____

Figure 1: Questions 2, 3 and 4 of the Knowledge of Learning Outcomes Questionnaire.

Q2 How would you rate your level of confidence in being able to explain the concept of a learning outcome to another person?

A summary of student responses to this question is presented in Figure 2. From this:

- Less than 5% of students stated that they were "very confident".
- Nearly 50% stated that they were "fairly confident", however nearly 50% stated that they were either unsure or not confident.

From reviewing the comments made by students, it is clear that those who stated they were "fairly confident" do not really have a good understanding of what a learning outcome is. For these students, learning outcomes are things that you know or understand from completing a course. For example, some of these student's comments include: "Learning outcomes – what you're supposed to know/taught at end of year"; "A learning outcome is simply what you are supposed to know at the end of the day". Overall, it can be concluded from the data that there is a need to educate students about the learning outcomes concept.

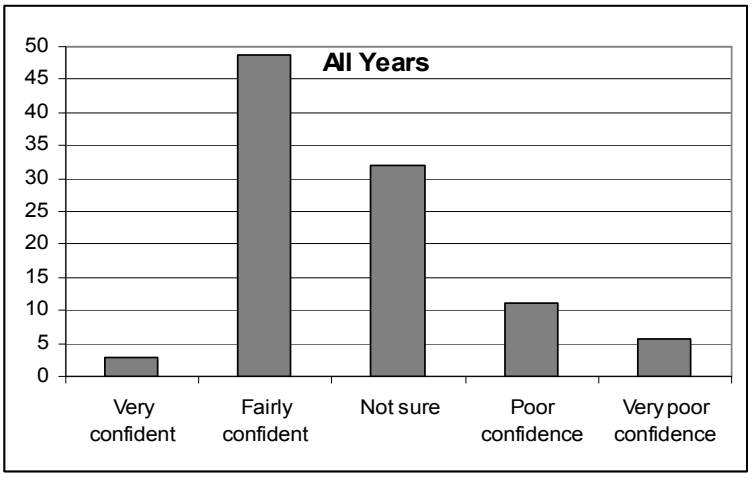

Figure 2: Summary of student responses to question 2

Q3. How would you rate your level of confidence in being able to write down the Learning Outcomes of your degree programme?

A summary of student responses to this question is presented in Figure 3. From this:

- Less than 2% of students stated that they were "very confident".
- Around 42% stated that they were "fairly confident", however over 50% stated that they were either unsure or not confident.

From reviewing the comments made by students, those who stated they were "fairly confident" are using their own perception to try and state what they would know or understand from completing a course. As stated by one of these students (2nd year), the students "have a rough idea of the course and the different topics to be covered". A 4th year student stated that a student "might be able to write about some of the outcomes, might not realise some of them". Another 2nd year student stated that the first year course "PE1003 was very helpful in defining the learning outcomes of this degree". This module did not explicitly state programme learning outcomes but gave an overview of chemical engineering, and in so doing, the degree programme. Overall, it can be concluded from the data that over half the students are not sure or have poor confidence and the rest have some perception of programme learning outcomes but in a general sense. Thus, there is a need to spell out in detail to the students what the learning outcomes of the degree programme are.

Figure 3: Summary of student responses to question 3

Q4. Has anyone in the Department explained to you what are the learning outcomes of the degree programme in Process & Chemical Engineering?

A summary of student responses to this question is presented in Figure 4. From this:

- Over 60% of the students stated "No", that is, the learning outcomes for the degree programme were not explained to them.

- The percentage number of "No"s is greater amongst the third and fourth years than the first and second years, however all years had a greater percentage of "No"s.

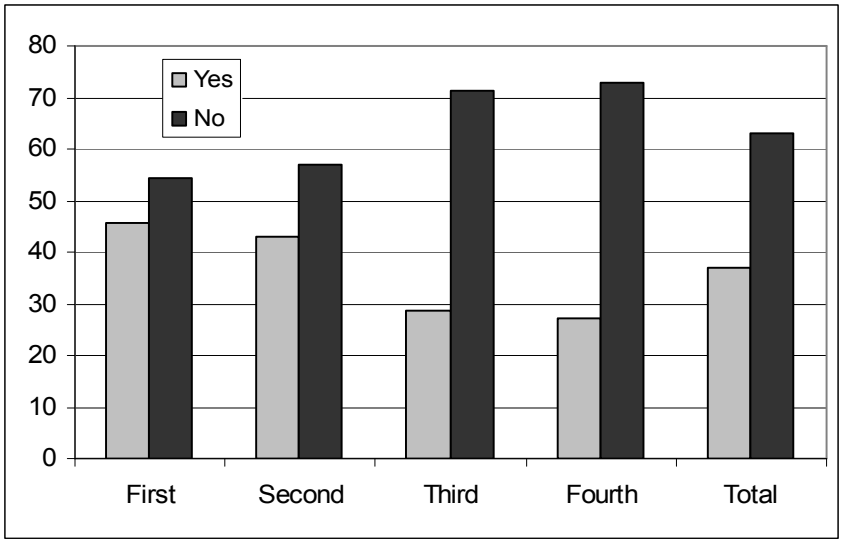

Figure 4: Summary of student responses to question 4

From viewing the student comments, it became clear that many of the students who stated "Yes" obtained their knowledge from one particular module (PE1003 Introduction to Process Engineering) taught by a member of staff to first year students. The programme learning outcomes do exist in the Department accreditation documents submitted to IChemE and EI, but it appears that these are not communicated to the students.

From this survey, it is clear that there is a need to present and explain the learning outcomes concept to students and to present the programme learning outcomes to the students. This survey acted as the motivation to formulate the programme learning

outcomes in a format suitable for students and to disseminate these and the concept of learning outcomes to the students.

4. Formulating programme learning outcomes

Following the survey, the formulation of the degree programme learning outcomes was undertaken. A first draft document was created and it consisted of 19 learning outcomes. These learning outcomes were created after reviewing the following documentation:

- Learning outcomes used in the guide-lines for accreditation of engineering undergraduate degree programmes by the Institution of Engineers of Ireland (2003).
- Learning outcomes used in the guide-lines for accreditation of chemical engineering degree programmes by the Institution of Chemical Engineers, UK (2005).
- Accreditation document submitted to the Institution of Engineers of Ireland by the Department of Process & Chemical Engineering UCC (2006). This was as part of an application for full accreditation with the Institution.
- Accreditation document submitted to Institution of Chemical Engineers, UK by the Department of Process & Chemical Engineering UCC (2005). This was as part of an application for full accreditation with the Institution.

The draft document was then circulated to the staff within the Department who lectured on the degree programme for their input. The staff gave their input through written comments and face to face meetings. The second draft incorporated the input from staff.

The major features of the document are as follows:

- Definition of the learning outcomes concept and its usefulness.
- Statement of the degree programme learning outcomes.
- Description of how the individual modules and their assessment are related to the degree programme learning outcomes.
- Provision of a short section which tries to relate the achievement of the degree with careers within the core of process and chemical engineering and to other career opportunities.

This was used as the basis for the creation of a PowerPoint presentation to be made to the first year and fourth year students. From giving the presentation and from feedback from the students, it was obvious that the first learning outcome was too broad and was consequently broken down into two learning outcomes, resulting in the third draft which consisted of 20 learning outcomes. A summary of the 20 degree programme learning outcomes is presented in Appendix A.

5. Communicating with the students

In the later part of 2007, a PowerPoint presentation, based on draft 2 of the learning outcomes document, was presented to the first year and fourth students. The students were also given the document at the beginning of the session. At the end of the session, a short questionnaire was given to the students to quantitatively evaluate if they had gained a better understanding of the learning outcomes concept, the degree programme learning outcomes and to gauge if they considered this type of session to be of any benefit to them. Questions 1, 2 and 3 of the questionnaire are presented in Figure 5. Analysis of the student responses is presented below for the first year and fourth year students.

1. How would you rate your level of confidence in being able to explain the concept of a learning outcome to another person?

☐ Very confident ☐ Fairly confident ☐ Not sure ☐ Poor confidence ☐ Very poor confidence

Please comment _____

_____

2. How would you rate your level of confidence in being able to write down the Learning Outcomes of your degree programme?

☐ Very confident ☐ Fairly confident ☐ Not sure ☐ Poor confidence ☐ Very poor confidence

Please comment _____

_____

3. How would you rate the session and document on Learning Outcomes?

☐ Very useful ☐ Useful ☐ Not sure ☐ Not very useful ☐ Waste of time

Please comment _____

_____

Figure 5: Questions 1, 2 and 3 of the questionnaire given to the students after the learning outcomes presentation.

5.1. Responses from first year students

Twenty-six of the 30 first year students attended the presentation and were surveyed afterwards. Analysis of their responses to the questions is presented below, including a summary of the comments made by the students:

Q1. How would you rate your level of confidence in being able to explain the concept of a learning outcome to another person?

Quantitative data on the responses of the first year students to Q1 is presented in Figure 6.

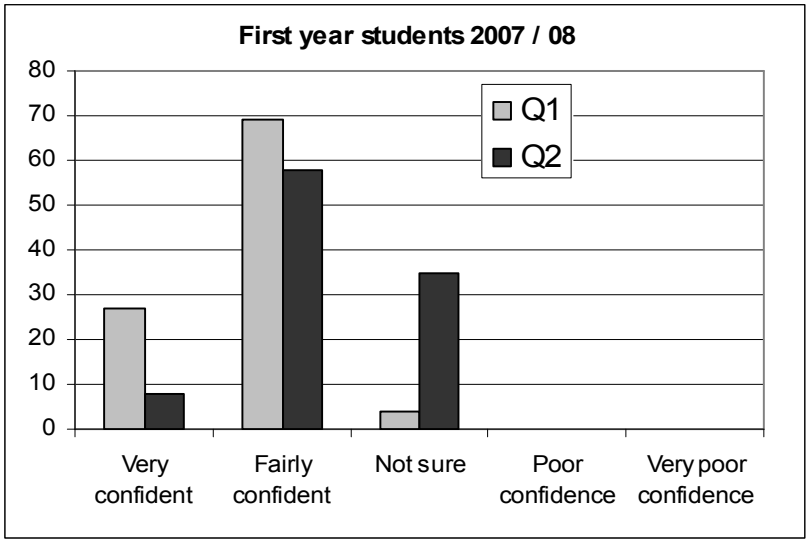

Figure 6: Responses of first year students to Q1 and Q2.

The major results are:

- 96% of students are confident of explaining the learning outcome concept.
- These data represent a major improvement in the understanding of learning outcomes and the degree programme learning outcomes where only 30%

expressed confidence when initially surveyed prior to the presentation in late 2007

The student comments regarding Q1 can be summarized by the following student statements. They "have now more knowledge of the exact definition of a learning outcome" and "it is a lot clearer now after the session". "It was made very clear in the presentation". One student remarked that "it is a hard concept to grasp".

Q2. How would you rate your level of confidence in being able to write down the Learning Outcomes of your degree programme?

Quantitative data on the responses of the first year students to Q2 is presented in Figure 6. The major results are:

- 65% of students are confident that they can write down most of the learning outcomes of the degree programme while 35% are unsure. None have poor confidence.
- These data represent a major improvement in the understanding of learning outcomes and the degree programme learning outcomes where only 30% expressed confidence when initially surveyed prior to the presentation in late 2007

The student comments regarding Q2 can be summarized by the following student statements. The programme learning outcomes "were very well explained in the presentation", however, "some may be more easily defined than others, some are still fairly unclear". The reason why some are unclear is because the students are "only in first year" and "it is more likely that LOs become more apparent as you progress" through the degree programme. Overall, the first year students gained " a fairly good idea of what the learning outcomes of the course are".

Q3. How would you rate the session and document on Learning Outcomes?

All students found the session beneficial with 65% rating it as very useful and 35% rating it as useful. The session also gave the first year students an insight into 2^{nd}, 3^{rd} and 4^{th} year.

The student comments regarding Q3 were very positive can be summarized by the following student statements. The session "gave me a good insight into what a learning outcome is and what I'm expected to know when I finish my course". "The session was very helpful as it gave us an insight into 2nd, 3rd, and 4th year". This is a recurring comment by many of the students where the session gave the first students an overview of what the courses was all about and what they would be doing in subsequent years. Overall, many of the students were enthused by the session and one student remarked that the session was "extremely interesting and the outcomes were laid out in a clear manner".

5.2. Responses from fourth year students

Only 11 of the 25 fourth year students attended the presentation and were surveyed afterwards. Analysis of their responses to the questions is similar to the first years and is presented below:

- ***Question 1:*** 82% of students were confident of explaining the learning outcome concept. 18% were still unsure while none expressed poor confidence. This represents a major improvement on the initial survey prior to the presentation where 48% were confident, 33% not sure and 14% were not confident. Student comments regarding Q1 state that the learning outcomes concept is "a simple concept once defined" and "from the presentation it is easy to understand what the term means". However, another student stated that "it is a difficult concept to someone unfamiliar with learning outcomes".
- ***Questions 2:*** 73% of students were confident that they could write down most of the learning outcomes of the degree programme while 18% were unsure and 9% had poor confidence. This represented a major improvement on the initial survey prior to the presentation where only 24% expressed confidence, 38% were unsure and 38% were not confident. The student comments demonstrated that they would be able to outline most of the learning outcomes in a general sense but not in the detail provided in the session.
- ***Question 3:*** 10 of the 11 students found the session beneficial with half of these rating it as very useful and half rating it as useful. One student was unsure of the usefulness of the session. A number of the students commented that it would be

beneficial to give this type of session to first year students. One student commented that "I found it useful to take a step back and find out what we've achieved in this course and its relevance to the working environment". Another student commented that this type of exercise "is very useful for interviews and looking and looking at areas apart form engineering". This is a very valid comment as being able to express your achievements in terms what you can do and the skills you possess can very impressive at interview. Also, many of the learning outcomes achieved can be applied to other employments outside of chemical engineering.

6. Conclusions

A questionnaire survey of the undergraduate students in the Department of Process & Chemical Engineering in UCC clearly showed that the majority had a poor knowledge of the learning outcomes concept and the degree programme learning outcomes. Some students had a perception of the degree programme learning outcomes, and this appears to originate from a first year module (PE 1003 Introduction to Process Engineering), which provides a general overview of process engineering to first year students. Programme learning outcomes do exist in the Department accreditation documents submitted to IChemE and IEI, but it appears that these are not communicated to the students.

The initial survey acted as the motivation for doing something to try and inform the students about the learning outcomes concept and the learning outcomes of the degree programme they were undertaking. This was undertaken by creating a document and preparing a PowerPoint presentation (based on the document) that outlined the programme learning outcomes of the degree programme and highlighted the modules that were striving to achieve them. This was then presented to first and fourth year students.

After the presentation, the students were surveyed to assess the impact of the presentation on them. The major impacts are as follows:

- It greatly improved their understanding of the learning outcomes concept and the degree programme learning outcomes.

- The students rated highly the presentation and stated that is was beneficial to them.
- Some fourth year students commented that this presentation would be very useful if given in first year.
- For the first year students, the presentation represented a "mapping out" of the whole degree programme in addition to communicating to them what they should achieve during their four years. It gave them a much clearer picture of what lay ahead for them in years 2, 3 and 4. It gave them a much greater connection to the core discipline of chemical engineering.

The above findings are consistent with other publications that discuss the advantages of learning outcomes. In general, it is found that learning outcomes help to explain more clearly to students what is expected of them and thus help to guide them in their studies giving them increased motivation and a sense of purpose (Adam, 2004; Allan, 1996) Based on the above, it was decided to provide the programme learning outcomes presentation and document to the first year and fourth year students on an annual basis moving into the future. The first years will receive this presentation as an integral part of the first year module PE1003. It is also hoped in a future study to interview a sample of first and fourth year students to ascertain their understanding of the concept of learning outcomes and also of their level of knowledge of the module and programme learning outcomes.

Even though this paper was based on a small case-study and therefore it is not suggested that the findings are applicable on a wide scale to similar programmes,, it is possibly true to state that some of the conclusions may be relevant to other engineering degree programmes. In particular, the need to formulate and communicate programme learning outcomes to students and to discuss the benefits they can gain from this activity.

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Appendix A. Summary of degree programme learning outcomes

A summary of the degree programme learning outcomes is presented in this appendix.

Twenty Learning Outcomes were created and they are presented below under eight headings:

A) Knowledge and Understanding of Mathematics, Science & Core Chemical Engineering

1. To demonstrate an understanding of the mathematics which underpin chemical engineering.

2. To demonstrate an understanding of the sciences (of chemistry, physics, biochemistry, microbiology and biotechnology) which underpin chemical engineering.

3. To demonstrate an understanding of core chemical engineering, including:

i. Creating and reading chemical engineering drawings (including P&ID diagrams).
ii. Developing, applying and evaluating mass an energy balances in chemical engineering analysis.
iii. Application of fluid mechanics to solving chemical engineering flow problems.
iv. Application of thermodynamics to chemical equilibria and reactions, and in understanding and solving energy problems.
v. Application of heat and mass transfer theory in process analysis, such as heat exchangers and separation processes.
vi. Application of kinetics and reactor analysis in the design and performance evaluation of chemical and biochemical reactors.

vii. To describe and analysis the function of a variety of unit operations found in the process industries.

viii. Application of control theory in chemical process control and automation.

B) Problem Solving

4. To derive expressions and apply solutions for quantitatively solving defined problems in chemical engineering using a knowledge of the sciences, engineering sciences, technology and mathematics.

5. To identify, formulate, analyse and solve engineering problems.

C) Social, Environmental and Economic Context

6. To demonstrate an awareness of industrial health and safety issues and be able to suggest and implement technologies and procedures for protecting human health and safety.

7. To demonstrate an awareness of the need for environmental protection and the concept of sustainability and be able to suggest and implement technologies and procedures for protecting the environment and achieving sustainable living.

8. To demonstrate an awareness of typical legal requirements on personnel, processes, plants and products relating to health, safety and environment.

9. To calculate and explain process, plant and project economics.

10. To demonstrate an appreciation of the need for high ethical and professional standards, and how they are applied to issues facing engineers.

D) Engineering Design

11. To perform process design of unit operations.

12. To perform basic mechanical design of process system components and unit operations.

13. To design an entire process to produce a product with defined specifications.

E) Practical / Transferable Skills

14. To apply the following skills:

i. Computer software
ii. Communication
iii. Work effectively as an individual
iv. Work effectively in teams and multi-disciplinary settings
v. Project management
vi. Laboratory / experimental skills
vii. Lifelong learning

F) Working as an Engineer in Practice

15. To demonstrate:

i. awareness of the application of chemical engineering skills to a variety of jobs and working environments.
ii. application of chemical engineering skills in a real work setting.

G) Research Skills

16. To apply the following research skills:

i. Literature review and knowledge acquisition – to identify the current state-of-the-art in a particular research topic and to find knowledge and techniques that are useful to the implementation of a research project.
ii. Apply statistical techniques in research, in particular, experimental design and establishing significant correlations.
iii. Conducting experimental / quantitative research work
iv. Data analysis and interpretation
v. Communication of research results and conclusions
vi. Managing research projects: planning, tasks, time, people and resources

H) Additional Knowledge and Skills

17. To demonstrate:

i. understanding of knowledge in **bioprocessing**,

ii. ability to deploy engineering methods to analyse and design the respective units and systems within this area.

18. To demonstrate:

iii. understanding of knowledge in **one of specialist streams** of pharmaceutical / food & bioprocessing / supply chain engineering and management,

iv. ability to deploy engineering methods to analyse and design the respective units and systems within those areas.

19. To implement validation procedures and documentation.

20. To demonstrate an awareness of business knowledge and skills in the successful commercialisation of products and services in a market economy.