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# Developing Graduate Attributes to meet the Grand Challenges: What Pedagogical Factors Influence The Development of Graduate Attributes and Does Engineering Education Ensure Graduates Can Address The Global Grand Challenges?

Una Beagon
*Technological University Dublin*, una.beagon@tudublin.ie

Brian Bowe
*Technological University Dublin*

# Developing Graduate Attributes to meet the Grand Challenges

## What pedagogical factors influence the development of graduate attributes and does engineering education ensure graduates can address the global grand challenges?

**U Beagon**
Assistant Head of School
School of Civil & Structural Engineering, Dublin Institute of Technology
Dublin, Ireland
E-mail: una.beagon@dit.ie

**B Bowe**
Head of Learning Development
College of Engineering and Built Environment, Dublin Institute of Technology
Dublin, Ireland
E-mail: brian.bowe@dit.ie

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## INTRODUCTION

My interest in preparing graduates for a successful career in industry stems from personal experience of employing graduates as civil and structural engineers in an engineering consultancy role. The range of skills, abilities and values of each graduate was varied, and it became apparent that academic achievement, whilst important was not the defining skill for achieving early responsibility or promotion within the company. More often, the graduate who was able to communicate well and self-direct his/her work was given more responsibility and opportunity. Many graduates would define early promotion, advanced responsibility and the associated increase in salary as the beginnings of a successful career in engineering consultancy.

My intent in this paper is to present a plan for a PhD research project to investigate how academic institutions and academics themselves can provide opportunities for students to develop the key skills required for a successful career in consulting engineering. Furthermore, I am interested not only in the skills required of the graduate of today, but the skills that will be required to meet the challenges we face in the future. This paper is presented with two aims. The first is to summarise the research plan and objectives. The second is to elicit critique and advice in the design of the study, including the research questions and the methodology proposed.

## 1 RESEARCH PURPOSE

A formulaic process was used to create the research questions for the study which consisted of identifying the subject, the topic and the research purpose [1]. The subject of the study relates to graduate attributes in civil and structural engineering programmes. The topic focuses on what factors determine the level to which students develop graduate attributes and if these attributes are sufficient to address the global grand challenges. The factors which may be considered could reflect societal issues (if we consider various countries), pedagogy, accrediting body standards, lecturer's sense of identity or knowledge of education, academic conceptions of teaching. The purpose of the study however could be defined as having a generative purpose, that which identifies ways to overcome problems, as described by Ritchie & Lewis [2]. The proposed outcome is to develop strategies and suggestions to improve processes within academic institutions, to develop the required attributes within students. Savin-Baden & Major [1] recommend the use of a purpose statement to help researchers frame the study and this is presented here:
*The purpose of this pragmatic study is to explain the factors which determine the level to which students develop graduate attributes in civil and structural engineering programmes and to propose strategies to ensure that graduates can address the global grand challenges of the future.*

## 2 LITERATURE REVIEW

The literature review was carried out thematically under the following concepts which were derived from the purpose statement; Graduate Attributes, Accreditation Requirements, Grand Challenges, Academic Conceptions of Teaching.

### 2.1 Graduate Attributes in Engineering Students

The concept of graduate attributes has become a key issue in the discussion of engineering education in recent years and acknowledgement of the importance of these attributes is abundant in the literature. Graduate attributes can also be defined as; soft skills, key skills, employability skills, generic skills, non-technical and transferable skills [3-11]. These terms are used interchangeably in the literature. There are varying views on not only the terminology used but on the list of desirable skills. The required skill set often differs depending on the industry and the employer characteristics considered. For example, those required for an engineering design consultancy differ from these needed for a manufacturing company or in a research career. Many skills however may be considered generic as they are considered invaluable regardless of the employer. [4-7, 10]. The first step in identifying the critical skills needed from an engineering context would of course include a literature review on previous research studies. This has been attempted before by Markes [5]. However, rather than clarifying the required skill set for engineering, Markes reported that the extent of literature published by variant organisations merely confused the definition and she concluded that further research is required to define "graduate skills for employability". This result concurred with my initial literature investigations which did not yield a clear distinct set of desirable attributes.

The outcome of this part of the literature review supported the decision to collect primary research data in relation to skills required for civil and structural engineering graduates. This data is required to provide a solid foundation on which to build the investigative part of the study.

### 2.2 Accreditation requirements

Accreditation requirements for engineering programmes also serve as a framework to set the agenda for programme design. Engineers Ireland (IEI), the accrediting body for Irish engineering programmes, require evidence that Bachelors Honours Degree programmes comply with seven programme outcomes (PO) [8]. The first four POs are considered 'technical' as they describe the ability to understand mathematics and engineering science, solve engineering problems, design systems or components and conduct research. The fifth PO relates to ethical responsibility both in the practice of engineering and toward people and the environment. The final two POs are key to developing some of the graduate attributes discussed in the literature. They relate to self-directed working, teamwork, multidisciplinary working and communication with the engineering community and with society at large. The programme outcomes have been developed in consultation with employers and should therefore address concerns about graduate attributes from an employer's perspective. Employers still report however, that they are not satisfied with the level of competence of engineering graduates in what may be termed non-technical skills. [9]. In 2011, the Institutes of Technology in Ireland commissioned a study to look at the strengths and weaknesses of engineering programmes using feedback from employers [9]. The report recommends that "The teaching of key non-technical skills such as oral and written communication should be enhanced and further integrated into the earlier years of the engineering programmes" [9, p.8]. This outcome would suggest therefore, that although there are processes in place which should ensure that students have opportunities to develop these skills, that there is a disparity between what happens in the classroom and the skills that students actually develop.

### 2.3 The Grand Challenges of the future

At the beginning of this project, my focus was centred on the attributes required of civil and structural graduates to serve the current engineering consultancy market in Ireland. However, I was encouraged to look forward and to consider the world in which we will live in 2050. This broadened my outlook on my initial research questions. It is clear that the skills required of graduates in a world of an estimated population of 9 billion trying to solve global grand challenges will require a different skill set to those required today [12,14].

In 1900, David Hilbert, a German mathematician, presented a paper to the International Congress of Mathematicians where he highlighted a list of mathematical problems which were unsolved. The result was a flurry of activity from his peers which propagated new discoveries and which greatly influenced 20th century mathematics. Using this model, in 2007, the National Academy of Engineering (NAE) in the United States (US), assembled a blue ribbon committee to identify the grand challenges and opportunities for engineers in the 21st Century and beyond. The aim of the project was to improve quality of life around the globe. The project culminated in the publication "Grand Challenges for Engineering" in 2008, which highlights 14 challenges identified by the committee. The categories of sustainability, health, vulnerability and the joy of living are used to describe the areas where grand challenges exist and where engineers can provide solutions [13].

In 2009, some prestigious colleges in the US devised the concept of the Grand Challenges Scholars programme (GCSP) [14-15]. The programme was envisaged as a way to train the new generation of engineers with the skills required to solve the grand challenges. Since then, there has been a significant tide of action within the US in an attempt not only to educate the public, but to provide engineering students with the skills necessary to solve the Grand Challenges [16-17]. However, outside the US

and despite two global summit events, there is limited evidence to show that other academic institutions have specifically addressed the concept within the engineering education field. This raised one of the questions within this research project: I hope to investigate if Irish engineers or academics are preparing graduates for a local market or with the skills and abilities to solve global problems. Furthermore, I intend to investigate if the GCSP has had an influence on the skills developed by graduates and what teaching pedagogies are used within the programme.

### 2.4 Academic Conceptions of Teaching

Several studies report that although there is an awareness of the importance of developing non-technical skills within students, academics do not always feel adequately prepared to teach these skills, nor feel compelled to change their teaching pedagogy [3,14,18-20]. If we assume that academics are a key driver for change in engineering education, then we need to ascertain what constitutes good teaching or more importantly good learning in relation to developing graduate attributes. The theory of academic conceptions of teaching provides a lens through which to consider this aspect. When academics enter the classroom, they do so with prior conceptions of what constitutes good learning and teaching in their discipline. Trigwell and Prosser [21] purport that the academic's conception of teaching has a direct influence on how the students learn. Since this theory emerged in 1991, several researchers have produced varying categories of descriptions of the conceptions of teaching [21-24]. However, Trigwell and Prosser [21] went further and developed an 'Approaches to Teaching Inventory' which is a survey instrument which can be used to identify which category best describes each survey respondent. The categories of Teaching Conceptions proposed are listed here:

A. Teaching as transmitting concepts of the syllabus
B. Teaching as transmitting the teacher's knowledge
C. Teaching as helping students acquire concepts of the syllabus
D. Teaching as helping students acquire teacher's knowledge
E. Teaching as helping students develop conceptions
F. Teaching as helping students change conceptions.

The scale varies from (A), academics who consider their role in teaching as transmitting information with the result that students respond by accumulating information and rote learning to (F), where teachers focus on their students' own views or conceptions of the subject, rather than their own. In this category, teaching pedagogies would likely include open discussions and debates so that students take ownership of their own views. One could conclude that the ability to critically examine and defend a position is one of the graduate attributes that employers are seeking. One aspect of this research study intends to explore if the academic conceptions of teaching bear any relation to how academics feel about 'teaching' graduate attributes.

## 3 RESEARCH QUESTIONS

The overarching research question for this study is therefore;

*What factors determine the level to which students develop graduate attributes in civil and structural engineering programmes and what strategies ensure that graduates are equipped to solve the global grand challenges of the future?*

In order to answer this question, there are several sub-questions which must first be investigated.

- What are the key graduate attributes required to achieve a successful career in civil and structural engineering from an academic, employer and recent graduate perspective?
- To what extent do academics, employers and recent graduates, contemplate the skills required to meet the global grand challenges of the future?
- How to academics feel about 'teaching' graduate attributes?
- To what extent do academic conceptions of learning influence the teaching of graduate attributes in civil & structural engineering students?
- What pedagogical practices expose students to situations which develop the key skills required and where are they assessed?
- What barriers exist in relation to the integration of graduate attributes within engineering programmes?

Commented [BB1]: These could change depending on how the research evolves as per my comments above.

## 4 METHODOLOGY

A mixed methods study is proposed which will include both quantitative survey questionnaires and qualitative open ended interviews. Creswell [25] describes this as a pragmatic approach as it allows the researcher to use various forms of data collection and analysis to provide the best understanding of the research problem. This approach also allows the researcher to choose various methods and procedures to best meet the needs of the research.

## 5 RESEARCH DESIGN

The research design considered both an explanatory sequential design and an exploratory sequential design. The explanatory design normally begins with a large scale quantitative survey, the outcomes of which are investigated in more detail by detailed qualitative interviews. The exploratory design is the reverse sequence. It starts with exploratory interviews which are then analysed and used to build a second quantitative phase such as a survey instrument [25].

I initially considered an explanatory design, where a large scale survey would be used to invite academics, employers and recent graduates to rank the most important graduate attributes in their view. This would require an initial list of graduate attributes to be prepared to administer the survey. Holmes [26] published an article in response to another study related to graduate identity and employability. Holmes's paper discussed the importance of a robust conceptual framework and he points out weaknesses in previous research studies. Perhaps most critically he highlights that there may be problems with the provenance of some lists which are used within ranked surveys. He notes that many are developed from other lists, the validity of which are taken for granted, but not necessarily demonstrated. It is because of this potential weakness that I have decided to collect primary data in the form of interviews as the first phase of the project. This follows the model of exploratory design.

### 5.1 Phase 1: Qualitative interviews with Academics, Employers and Recent Graduates

Open ended questions will be used in the Phase 1 interviews as described overleaf in *Fig. 1*.

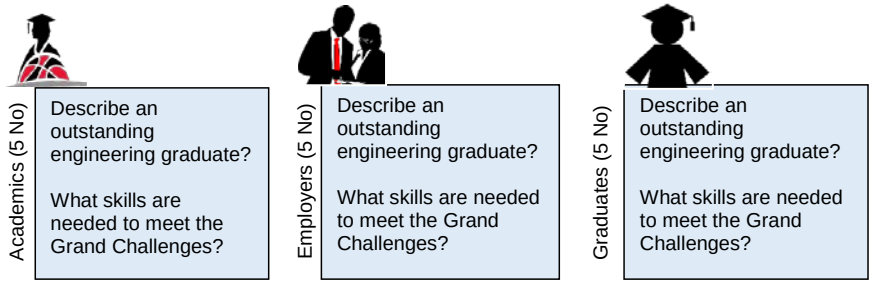


*Fig. 1.* Phase 1: Qualitative interviews with Academics, Employers and Graduates

The academics, employers and recent graduates for the initial interviews will be recruited from contacts within different academic Institutions and personal contacts from industry. The aim is to select a diverse range of interviewees based on rank, gender and time spent within each subgroup. Exploratory questions will be tested with one person from each subgroup who meets the criteria but will not be included in the final sample.

### 5.2 Phase 2: Identify a list of graduate attributes

The interviews will be transcribed and coded in line with the recommendations of Miles and Huberman [27]. Categories or themes will be collated and reviewed by another coder for validity. These categories will form the list of desirable graduate attributes to be used as a basis of the Phase 3 online survey.

### 5.3 Phase 3: Online survey

An online survey will be circulated with a list of desirable graduate attributes which have been ascertained from the interview data. Respondents will be asked to rank these in order, both for the attributes required for current graduates and the attributes required to solve the global grand challenges of the future as shown in *Fig. 2.*

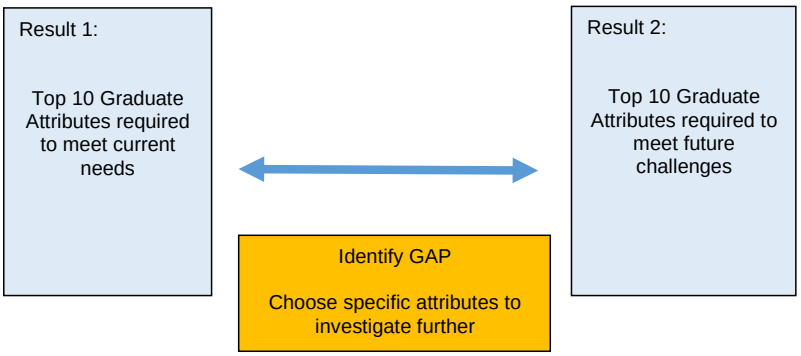


*Fig. 2.* Phase 3: Online survey results will identify a gap in current and future needs

The survey results will compare and contrast the skills requirements in each category. They will highlight specific gaps between current needs and the needs of the future which will inform the questions for Phase 4 of the project.

At this point, the exploratory sequential design is complete. However, the research goal of this project is to determine how academics can influence the learning and teaching of the required skills.

### 5.4 Phase 4: In depth interviews with Academics

A pragmatic research methodology allows the researcher to use different methods of data collection and analysis and it is therefore proposed that Phase 5 of the study will proceed with in-depth interviews with academic staff to further investigate the academics views on the teaching and assessment of graduate attributes as indicated in *Fig. 3*. This phase is considered to be an explanatory phase.

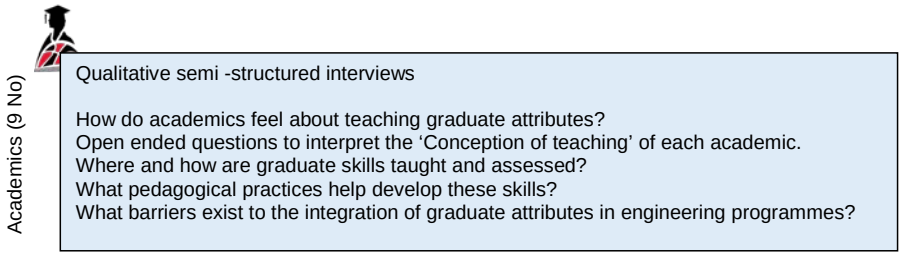


*Fig. 3*. Phase 4: Semi-structured interviews with academics

The research design proposed in this project may be termed a multiphase mixed methods as it proposes a combination of both of the exploratory and explanatory sequential research designs [25].

### 5.1 Sample

Phase 1 of the research will require a purposeful sample of academics, employers and recent graduates from a range of academic Institutions in Ireland and the UK. The online survey in Phase 3 shall be circulated widely, to academics, employers and recent graduates from various Institutions within Europe and America.

Phase 5 will involve in-depth interviews with academics and it proposed that this will be purposely split to investigate attitudes and experiences of academics in different types of academic institutions, such as;

- An Irish Institute of Technology
- An Irish University whose programme has been designed using Problem Based Learning (PBL)
- An American University delivering the Grand Challenges Scholars Programme
- A European University which is based upon a PBL model of teaching such as Aalborg University.

## 6 SUMMARY

This paper presents a research plan for a PhD project to investigate "*What factors determine the level to which students develop graduate attributes in civil and structural engineering programmes and what strategies ensure that graduates are equipped to solve the global grand challenges of the future?"*

The proposed output from this study is a handbook for academic institutions and accrediting bodies to provide a framework to enhance programme design in relation to graduate attributes for Civil & Structural engineering programmes.

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