2018-5

Creativity as a Graduate Attribute

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Funder: DIT

School of Education

Doctor in Education (D.Ed)

COVER SHEET

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MODULE TITLE	Frontier Research and Current Debates
TITLE OF ASSIGNMENT	Position Paper: Creativity as a Graduate Attribute in Civil Engineering
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DATE SUBMITTED	4/5/2018

Position Paper: Creativity as a Graduate Attribute in Civil Engineering

Submitted in part fulfilment of the D.Ed programme, Year 1

Module: Frontier Research and Current Debates

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Student Number: 17315977

Word Count: 2197

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Abstract

This position paper examines the value, delivery and assessment of creativity as a graduate attribute in civil engineering. Creativity is an essential skill for modern civil engineering graduates to allow them to respond to the variety of challenges within the industry. In addition, the need for creativity within their work is both directly and indirectly referenced within accreditation requirements from engineering professional bodies.

How to deliver on creativity as a learning outcome requires time and space within the timetable, a difficult challenge in the technical content heavy subjects the make up civil engineering programmes. Added to this are the difficulties presented by tight timetables in modularised programmes and restrictions on availability of teaching staff. Delivery also requires physical space to provide collaborative learning environments which nurture such skills. Mention is also made of the need to partner creativity with critical thinking as an attribute in order that creative solutions are also practicable.

1 Introduction

The role of the civil engineering graduate requires response to many different factors in the modern engineering industry. For example, students and graduates need to be informed in the area of sustainability, the circular economy, adhere to Engineers Ireland Code of Ethics (2018) and Accreditation Criteria (2014) in addition to responding to client requirements for technical solutions in a variety of circumstances.

As such, creativity is an essential skill to foster during the education experience so it is well developed by the time the student graduates and is employed. Nordstrom & Karpelainen (2011) discuss the struggles faced by modern engineering education, being technical-content-heavy with the associated concentration of objectivist pedagogy. This often leaves like room in engineering programmes for the design or problem solving teaching approaches or work experience/ placements which might include the autonomy which encourages the development of creativity (Nordstrom & Karpelainen 2011, Rampersand, 2016) However, as mentioned above, and discussed further in Section 2 below, creativity is the basis for innovation in problem solving in engineering work. Thus it is a core graduate attribute and as such, its development must be afforded more attention in curriculum design. This position paper discusses the importance of creativity, how it fits into civil engineering education in Ireland and how it might be assessed by educators.

The Institute of Engineering and Technology (IET, 2017) discusses the role of creativity in the engineering sector, stating that while creativity is often overlooked, engineers are essentially creative problem solvers. In his article, The Creative Engineer, Selinger (2004) defines creativity as:

" the quality of making, inventing, or producing--rather than imitating--and it's characterized by originality and imagination"

He goes on to discuss the image that engineers have as being uncreative, due, he posits, to the fact that often engineering solutions are not created from a "blank page" but build on previous work, making changes incrementally and so maybe do not appear as obviously creative or ground-breaking.
Also worth discussing is the breakdown of creativity offered by Hennessey, Amabile, and Mueller (2011) as cited in Denson et al (2015). They split creativity into two aspects: Conceptual creativity - creative to the extent that something is both a novel and appropriate, useful, correct, or valuable response to an open-ended task and Operational creativity - Something is considered creative to the extent that appropriately skilled evaluators agree that it is creative.

2 Role of creativity in engineering: how does it manifest in the evaluation of civil engineering education?

The International Engineering Alliance, the global organisation which coordinates agreements between national engineering accreditation bodies (IEA, 2018), has defined graduate attributes as they should be reflected in the programme outcomes of the varying national accreditation bodies. As these programme outcomes in turn shape the learning outcomes of the varying accredited engineering programmes, the definitions of the various graduate attributes stem from the IEA. Excerpted below are the definition of graduate attributes which, either directly or indirectly, require a student to demonstrate creativity (and critical analysis) in their work as an engineer.

Table 1 Grade Attribute definitions, adapted from IEA, 2013, pp 10-11

Graduate Attribute Profile	
Differentiating Characteristic	**Interpretation for Engineering graduates (Level 8, BEng)**
Problem Analysis: Complexity of analysis	*"Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions..."*
Design/ development of solutions: Breadth and uniqueness of engineering problems i.e. the extent to which problems are original and to which solutions have previously been identified or codified	*"Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations"*
Investigation: Breadth and depth of investigation and experimentation	*"Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions".*
Modern Tool Usage: Level of understanding of the appropriateness of the tool	*"Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations"*
The Engineer and Society: Level of knowledge and responsibility	*"Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems"*
Environment and Sustainability: Type of solutions.	*"Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts."*

It can be seen from Table 1 that while the graduate attribute profiles as defined by the IEA do not specifically or overtly mention creativity, the suggested interpretations for level 8 programmes, for each profile do suggest the need for creativity as a graduate attribute in order to achieve the goals of accredited programmes. As such, these programmes must include and be able to demonstrate that students acquire these attributes during accredited programmes.

3 Role of critical thinking as an adjunct graduate attribute

Creativity cannot exist as a skill on its own however, it must be used in conjunction with critical thinking in order that students/ graduates evaluate creative solutions as to their suitability, practicality or viability. Ahern et al (2012), in their study of the attitudes of third level teaching staff from various disciplines, found that while definitions of critical thinking were similar, there were variations in how well defined the concept was and how that definition had been achieved. The study found that "non-technical" disciplines e.g sociology, history, law had better elucidated definitions than those of "technical" subjects such as engineering, architecture and physics. While those teaching in the technical subjects considered critical thinking to be an important attribute, they had difficulty in giving an actual definition or explanation. The authors note that this would make it difficult to properly deliver and assess the critical thinking as a graduate attribute unless it is clearly defined. By extrapolation, the same could be said of creativity.

A further point from the staff interviews conducted in the above mentioned study was that the large amount of technical content to be covered often reduced the time for introducing attributes such as critical thinking, and in this author's experience, creativity. This is despite the fact that these attributes are clearly desirable or overtly required by accreditation bodies.

In reference to the study by Rampersad (2016) no mention is made of the quality of student's creative or innovative solutions. The autonomy developed by the students studying their work placement experience must be coupled with critical thinking in order for creativity to be of any practical use. Selinger (2004) mentions the fact that engineers do not usually start with a "blank page" but instead build on design precedent. This allows for a reduction in the critical analysis of an idea as some or most of it had been tried and tested before, which, it could be argued, then allows for creativity and critical analysis of smaller parts of a project within the often tight timeframes invoiced in modern engineering work.

4 How can creativity as an attribute be delivered in civil engineering education?

Rampersad et al (2016) found that creativity was a graduate attribute that could be both taught and learned. This study examined the delivery of creativity as a graduate attribute through the medium of Work Integrated Learning (WIL) wherein students are immersed in work environments through placement, giving them an opportunity to utilise professional competencies in a real working environment with a degree of autonomy. Assessment in this study was done through final reports from both students and employers and log books of weekly reflective writing by students.

Within the employer reports, employers were queried explicitly in how they considered that the students had performed in relation to creativity in their work.

This study was performed through a university with a solid reputation for WlL placements and used a small group of students. Students were supervised by industry staff at senior management level. What is not made clear in this paper however, is the whether or not there was a structured system in place within each placement which would guide a student in the development of such skills as creativity in the autonomy of the WIL placement.

An interesting point to note with regard to this study (potentially worth investigating in an Irish context) is the impact of improved self-efficacy and autonomy on a student's ability to express and develop creativity.
Forest et al (2014) once again make the point that while creativity and innovation are “championed as central pillars of engineering education” rarely is the development of such nebulous skills truly fostered in the university environment. They give an account of a novel space “The Invention Studio” at Georgia Institute of Technology, a 3000 sq ft flexible use space. This is used my multi-discipline engineering to develop graduate attributes of creativity, innovation and invention, free of the confines of the traditional classroom.

4.1 Collaborative learning environment

Barrie (2006) states that collaborative learning environments, along with social interaction, enhances the acquisition of graduate attributes such as critical thinking, Collaborative learning environments allow students some freedom and autonomy, with guidance from, as termed by Vygotsky, More Knowledgable Others (MKO) (Vygotsky, 2016). This guidance and support is key to allow students to feel they can experiment with creative solutions, and associated critical analysis, without feeling adrift or lacking in support. Barkley (2005) cite a number of studies which indicate that well-run collaborative learning sessions result in higher satisfaction from students.

5 Assessment and Teaching Workload Implications

It is in this area where the strongest counter argument can be made to the valuing of creativity in civil engineering programmes. It is clear from studies like Rampersad (2016) and Forest et al (2014) that creativity is valued enough for third level institutions to make room both physically and within their timetables, for its development. However, modularisation and the technical-content-heavy nature of engineering, along with pressures of accreditation requirements mean that there can be reluctance to make changes.
As discussed in Rampersad (2016), one option for the assessment of students’ creativity is to query students directly through the use of final reports and reflective writing. This would of course be in addition to the assessment of any technical content if applied through an in - house module (as opposed to external work placement). While potentially effective and thorough, this could lead to the need for increased numbers of staff to review student work. Similarly, Wright, Millar, Kosciuk, Penberthy, Williams & Wampold (1998) conducted a study on the effectiveness of collaborative learning on learning and found that it could only be properly assessed through interview of students by members of staff not involved in the original project. This could be applied to the assessment of the acquisition of creativity but as in the Wright et al study, the issue of increased staff numbers and timetabling would arise.
Nordstrom & Korpelainen (2011) used feedback forms to determine the level of creative skill development in their study of microbiology students, varying collection points between start middle and end of course of study. This study did not specify creativity directly however as a learning outcome. Instead, creativity was indirectly developed through the variety of tools that students b could use to carry

out the assignment. E.g. " *materials and dimensions for building and visualizing, such as drawing, legos', modeling clay, knitting machine, videos, movies, welding, electronics*, *music*".
This study noted that the total time spent on the module, by teaching staff, increased from 136-146 hours to 164-174 hours. This aspect could mean it would be extremely difficult to implement widely in the current Irish civil engineering education context.

Passig & Cohen (2014) present a similar variation of how creativity might be assessed in education, utilising a grading systembased on various levels of innovation: "incremental", "modular", "architectural", and "radical" innovation.
Denson et al (2015) present a method they term, Consensual Assessment Technique (CAT), where in evaluation assessment of creative products by is performed by a panels of raters.
It can be seen from a review of the research that by far the most common approach in assessing creativity is the interview/questionnaire/reflection method. This would indicate that assessment of creativity cannot be determined from assessment of presentation of technical knowledge alone but must involve some deeper querying. The questionnaire/interview method could be used to assess creativity both conceptual and operational, referring to the split definition presented in Section 3 above.

6 Application of creativity as a graduate attribute in civil engineering education

Review of accreditation requirements would indicate that there is no doubt that creativity is an essential requirement for civil engineering graduates. Review of literature indicates it requires novel approaches in both how it is delivered (collaborative learning, open working spaces, work experience) and how it is assessed (interview, questionnaire, reflective writing). Counter arguments can be made that , within already tight timetable and staffing limits, technical content is more important that more nebulous skills and that creativity and critical thinking will develop along the way. However, the author would question that is educators cannot define creativity adequately, do not specifically build it into their teaching or show how it assessed, can it be shown to have been delivered?

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