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Research topics that prove challenging for engineering students in a problem-based learning module

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ABSTRACT: Power engineering students need to complete a compulsory 36 credit problem-based learning module, called Industrial Projects 4, as part of an engineering Bachelor's degree. The primary aim of this module, also termed a capstone module, is to help prepare student graduates for their next higher qualification, being a Master's degree in engineering. This module does not involve the actual construction of an engineering project, but rather features case studies from industry where million-dollar projects need to be implemented. Various topics are covered by the students that include network and feeder strengthening, upgrading and refurbishment of substations, and the design of a new power network. The purpose of this research is to analyse which research topics proved more challenging for students to complete over a four-year period, to determine where more academic student support is required. Twelve main research topics were identified with the most challenging relating to the design and installation of new power systems. Student grade averages for each of the 12 topics suggest that they just managed to pass the module, with only seven out of 350 students achieving 75% or more over the four-year period. A recommendation is to channel additional academic support to future students who undertake similar challenging topics to possibly improve their chances of academic success.

Keywords: Graduate attributes, engineering design, industry

INTRODUCTION

> *In order to arrive at knowledge of the motions of birds in the air, it is first necessary to acquire knowledge of the winds, which we will prove by the motions of water in itself, and this knowledge will be a step enabling us to arrive at the knowledge of beings that fly between the air and the wind* [1].

These words, by the well-known painter Leonardo da Vinci, clearly illustrate that humans needed to gain knowledge of wind and of water motions to *enable* one to better understand the flight of birds and that of flight itself. Similarly, students need to first acquire knowledge of specific graduate attributes required by a university or accreditation council, before that can successfully demonstrate them in an educational context. However, simply having this knowledge does not guarantee the successful demonstration of them. More is required in the form of application.

Yes, students in higher education need to put into practice the theory that they have acquired to be able to demonstrate the acquisition of important graduate attributes. This application of knowledge is often more important than the possession of knowledge itself [2].

Fusing theory and practice has been mandated for many years [3] and is vital if students are to meet the demands of industry that finds itself amidst the 4th Industrial Revolution. Many believe that an innovative system of education is required with the aim to better develop a students' ability to project thinking, self-education and reflection [4]. One way of helping students achieve this aim is by using a capstone module.

The purpose of a capstone module is to provide students with the opportunity of integrating and applying knowledge and skills acquired from other modules, so as to extract the best possible benefit from the programme in a particular career [5]. This often involves the design and development of a project [6], with problem-based learning featuring predominately in these modules [7]. However, it has been documented that some engineering students struggle with problem-based learning [8][9] and in completing a design projects or industrial projects, module approximately 70% of students achieve success [10]. These challenges may relate to the number of different submissions that are required or that students fail to apply academic feedback given on their formative assessments [11]; thereby, indicating a lack of student engagement. Another challenge may relate to the student's perceived difficulty of a specific research topic.

The purpose of this research is to analyse which research topics, over a four-year period in a compulsory capstone module, proved more challenging for students to complete, in order to determine where further academic student support is required. An *ex-post-facto* study is employed along with descriptive statistics involving quantitative analysis of the collected data.

A discussion on graduate attributes and their importance from the standpoint of the Engineering Council of South Africa (ECSA) is firstly given. The ECSA is responsible for accrediting all engineering programmes in South Africa (SA) to ensure that they adhere to high standards of quality and integrity that have been set. It then considers typical research topics that are often undertaken by postgraduate students in power engineering. The study context is then given, followed by the research methodology. Results and conclusions round off the discussion.

GRADUATE ATTRIBUTES

Graduate attributes have become part of many different types of qualifications around the globe as universities attempt to respond to the call by industry and professional bodies that graduates attributes be embedded into their curricula [12].

Universities have to cultivate the required skills and abilities amongst their graduates in order for them to demonstrate key attributes [13]. Graduate attributes are not generally considered as learning outcomes that are integrated into the curriculum, but rather as a set of generic outcomes that need to be implemented within the learning environment.

Graduate attributes have become the norm among engineering qualifications in SA, as it forms a set of accessible outcomes that is indicative of the graduates potential to acquire competence at a specific level [14]. The International Engineering Alliance (IEA), that adheres to the Washington, Sydney and Dublin Accords, has stipulated 12 graduate attributes [15].

A repeating ECSA attribute (termed GA7 and called Sustainability and Impact of Engineering Activity) may be correlated to two separate IEA attributes (the engineer and society; and environment and sustainability). GA8 (called individual, team and multidisciplinary work) may also be correlated to two IEA attributes (individual and teamwork; project management and finance). However, all 10 of the ECSA attributes are linked to the IEA attributes, thereby indicating the international relevance of the engineering Bachelor’s degree in SA.

These graduate attributes need to be demonstrated by all engineering students over the course of an entire curriculum. They may be assessed at a basic level with first-year engineering students, at an intermediate level with second-year students and at an advanced level with senior engineering students. It is really this advanced level that attracts the attention of the ECSA, where specific evidence must be provided that each student has adequately demonstrated the acquisition of each of the ten stipulated attributes.

INDUSTRIAL PROJECT RESEARCH TOPICS

In this section, typical power engineering research topics are highlighted. Many of the Industrial Projects 4 (IP4) students are working at ESKOM (national energy supplier in SA) and thus, most of the projects are network and feeder related. Projects mainly focus on upgrading, extending, improving and design of distribution networks. Furthermore, projects can focus on the feeders themselves that may include splitting, extending or strengthening them. There are also projects regarding the connection of alternative energies to the distribution network.

The topics of the power engineering students may be correlated to some research titles from existing literature. These include:

- Multi-objective dynamic distribution feeder reconfiguration in automated distribution systems [16].
- Fault location in power distribution network with presence of distributed generation resources using the impedance-based method and applying π line model [17].
- Voltage control of distribution networks with photovoltaic power generation systems [18].
- Advanced feeder design for distributed generation [19].
- Photovoltaic penetration issues and impacts in distribution network - a review [20].
- Extended fast decoupled power flow for reconfiguration networks in distribution systems [21].
- Real-time implementation and evaluation of grid-connected microgrid energy management systems [22].

STUDY CONTEXT

Industrial Projects 4 (IP4) is a compulsory module in the Baccalaureus Technologiae: Engineering: Electrical qualification (more commonly referred to as the BTech). The module contributes 36 credits to the required 120 credits to complete the qualification. This means that students need to devote at least 360 hours to this module, which comprises six different submissions over a period of one year, as shown in Table 1 (registration commences in January and February with the final report due in October).

Table 1: Industrial Projects 4 (IP4) structure.

Requirement	Assignment	Month	Weighting
Registration		January and February	0%
Project proposal (formative)	1	April	10%
Progress report (formative)	2	July	10%
Article (summative)	3	August	5%
Poster (summative)	4	August	5%
Oral defense (summative)	5	September	10%
Final report (summative)	6	October	60%
		Total	100%

No formal electrical or electronic-based circuit or project work is required from these students who often work on high voltage systems. The final report or dissertation is usually based on a real-life case study, which was identified in the industry. Table 2 correlates seven of the ten graduate attributes of the Central University of Technology (CUT) to the six requirements of the IP4 module. It also shows the correlated ECSA graduate attributes on the right-hand side.

Table 2: Graduate attributes required in IP4.

Requirement	CUT graduate attributes (7 of 10 shown)							ECSA graduate attributes for the engineering Bachelor's degree									
	Problem solving	Community engagement	Technological literacy	Numeracy	Teamwork	Communication	Technical literacy	GA1 - Problem solving	GA2 - Application of scientific and engineering knowledge	GA3 - Engineering design	GA4 - Investigations, experiments and data analysis	GA5 - Engineering methods, skills, tools, including information technology	GA6 - Professional and technical communication	GA7 - Sustainability and impact of engineering activity	GA8 - Individual, team and multidisciplinary work	GA9 - Independent learning	GA10 - Engineering professionalism
Pr		√	√	√		√			√		√	√	√	√			√
Pr			√	√	√	√			√		√	√	√	√	√	√	√
A			√			√						√	√				
P			√			√						√	√				
O			√			√						√	√				
Fi	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

The most dominant attributes from the CUT are technological literacy and communication that may be correlated to the attributes of ECSA that are called engineering methods, skills, tools, including information technology and professional and technical communication. The use of MS Word, MS Excel, MS Power-Point and other software simulations are critical to each of the six submissions where technical information needs to be communicated in a professional way. Although the final report may contain all of the ECSA graduate attributes at an intermediate level, it would be used to demonstrate the achievement of problem-solving, engineering design, investigations, experiments and data analysis, impact of engineering activity, independent learning and engineering professionalism at an advanced level.

RESEARCH METHODOLOGY

An *ex-post-facto* study is employed along with descriptive statistics involving quantitative analysis of the collected data. This study is one where the investigator tries to trace an effect that has already been produced, to its probable causes [23]. In this study, the effect is the final grade marks of power engineering students in a capstone module with a probable cause being the type of research topics that they have chosen.

Descriptive statistics are used to present the quantitative data in the form of figures and is interpreted only with regard to these students.

The quantitative data focus on the research topics and final grades of all power engineering students over a four-year period, from 2014 to 2018. This equates to a sample size of 350. The research topics were included in a MS Excel sheet along with the final grades. The *countif* statement was then used to count the number of times that key words were used in all the topics.

For example, one of the topics was listed as upgrading and refurbishment of the 11/22/88kV Vrede switching station. The keyword *upgrading* was then used with the *countif* statement to locate another 153 *similia* topics in the spreadsheet. The *countifs* statement was then used to count how many of these *upgrading* topics of the students were awarded more than 50%, being the pass mark for this module. The *sumifs* statement was then used to sum the grades for each topic, which were then used to calculate the average grades obtained for each topic.

RESULTS

Figure 1 highlights the 12 main topics that were identified over the four-year period. The most popular topic relates to upgrading and refurbishment (153 students focussed on this topic that usually involves a substation or main line). The least popular topic relates to the splitting of a feeder (four students) or the incorporation of a new grid-tied connection (five students).

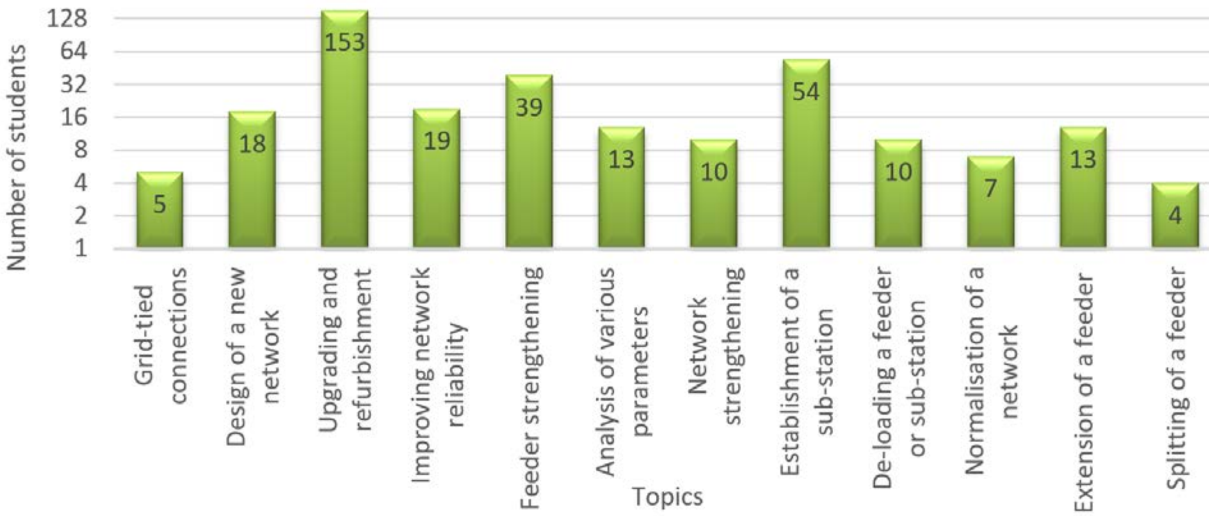

Figure 1: Main research topics identified from 345 IP4 completed by students over a four-year period.

Figure 2 shows the student success rates with regard to the 12 main topics, where students who focussed on the splitting or extension of a feeder proved to be the most successful (100% of four students and 92% of 13 students passed the module - number of students evident in Figure 1).

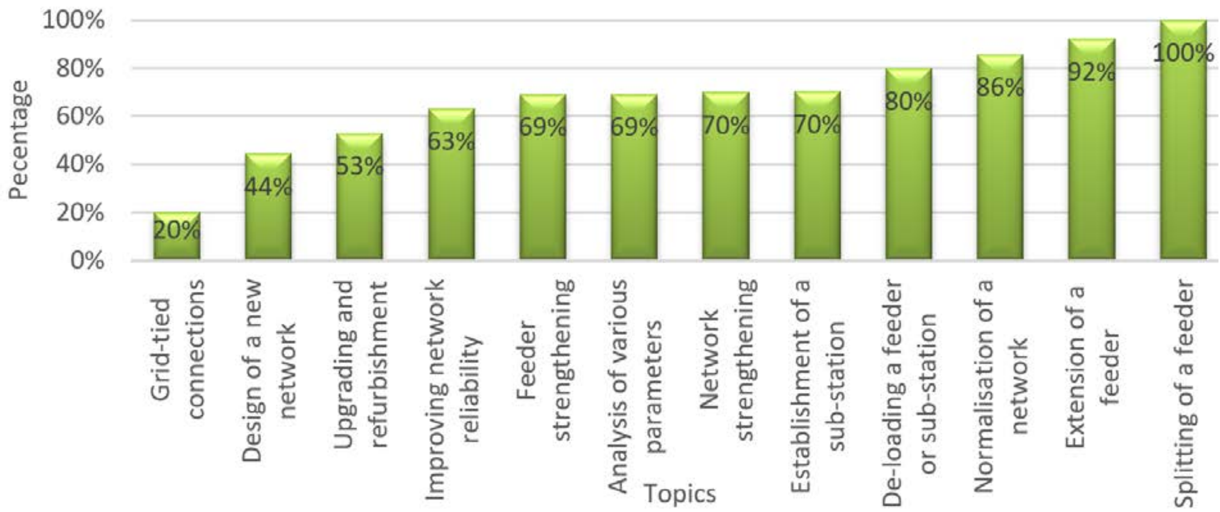

Figure 2: Students success rate with regard to the main research topics over a four-year period.

Figure 3 presents the average grades obtained by the students for the 12 main topics. Only seven distinctions were awarded over the four-year period, of which two were noted in the research topic of feeder strengthening. Even though the top three successful research topics showed a student success rate of more than 80% (Figure 2), the averages indicate that many of these students just managed to pass the module (averages between 50 and 56 were noted).

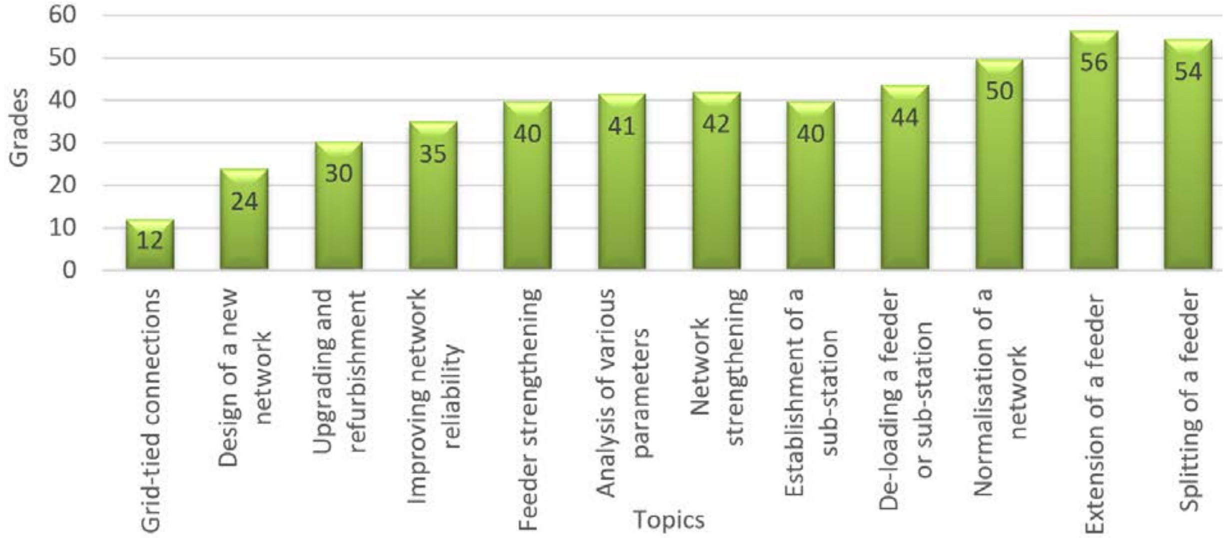

Figure 3: Average grades obtained with regard to the main research topics over a four-year period.

CONCLUSIONS

The purpose of this research was to analyse which research topics, over a four-year period in a compulsory capstone module, proved more challenging for students to complete. The majority of power engineering students were able to successfully complete ten out of the 12 main research topics identified in this study. However, the grade averages suggest that they just managed to pass the module, with only seven distinctions (75% or more) being awarded over the four-year period. This suggests that power engineering students are also struggling with problem-based learning in a compulsory capstone module that is designed to prepare them for a Master's degree in engineering.

Two topics that were not that challenging to these students related to feeders, being the splitting and extension of them. This would not really require any significant design skills, as no new major installation was required. These students would have been able to demonstrate several of the graduate attributes of ECSA, except for engineering design.

Students who attempted to demonstrate engineering design where not that successful. This is evident from the two main challenging topics that related to the design and installation of grid-tied power systems (alternative energy systems, such as solar, wind and diesel generation) and of new power network distributions. A recommendation is, therefore, made to channel additional academic support to future students who undertake similar challenging topics to possibly improve their chances of academic success. This could include strengthening their design skills by focusing more on principles of design-based learning.

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