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Activities Suitable for The Development of Graduate Attributes Among Senior Engineering Students

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Abstract

A challenge that is currently faced by many engineering educators around the globe is a lack of knowledge of what graduate attributes really entail and how they should be integrated and assessed in the curricula. The learned experiences of academics who have successfully assessed some of these attributes in their respective modules may help fellow academics in meeting this challenge. The purpose of this article is to highlight what activities an academic has used to help senior engineering students demonstrate two of the 11 graduate attributes required by a national engineering council that may help fellow academics, not to repeat mistakes, but rather achieve success in meeting the expectations of a statutory body. A descriptive case study is used which aims to provide a description of a phenomenon (activities used to help students demonstrate the acquisition of two graduate attributes) within a given context (a higher education qualification in engineering). The qualification was successfully accredited by the Engineering Council of South Africa in 2022, where exit-level modules featuring graduate attributes at the advanced level were scrutinized. This testifies to the validity of the activities used in this regard. The practical grades of students within this module indicate that the activities were neither to challenging nor to complex. The average grade for the activities for 2021 and 2022 for 371 students was 65%. It is recommended that academics continue to share their experiences with regard to the development of graduate attributes, as this will continue to contribute to the dialogue and help guide fellow academics in meeting the ongoing challenge of integrating and assessing them.

Keywords: engineering professionalism, engineering management, accreditation

1. Introduction

Albert Einstein is reported to have said: “The only source of knowledge is experience” [1]. These words ring true when it comes to the learned experiences of researchers that have helped to shape new knowledge. Furthermore, knowledge in terms of what to pursue or what to avoid in finding success in life or in one’s career is also invaluable today. One career where knowledge is indispensable is that of an academic in higher education who is tasked with both the dissemination and creation of new knowledge.

The dissemination of knowledge often entails assessment to determine if students have achieved the learning outcomes of a specific course or module or have demonstrated key graduate attributes (GAs) required by statutory bodies around the globe. Assessment has been called the most important element of pedagogy [2] helping students to become more knowledgeable, critical, competent and responsive [3]. The word “competent” is critical to GAs, as statutory bodies, such as the Engineering Council of South Africa (ECSA), often require institutions to indicate if students were “competent” or “not competent” in demonstrating the achievement of specific attributes relevant to a given

qualification. The word “competent” may be defined as “having the necessary ability or skills able to do something well or well enough to meet a standard” [4]. Abilities and skills are vital in engineering which often requires “hands-on” experience which may be demonstrated by students that are required to complete specific activities as part of practical assignments within a given module.

The learned experiences of academics who have successfully assessed specific GAs in their respective modules is valuable to share with fellow academics for at least two reasons. Firstly, engineering accreditation bodies around the world have placed more emphasis on producing graduates with the right attributes that are currently demanded by Industry [5]. Secondly, embedding and assessing GAs across a curriculum remains challenging [6]. Subsequently, the purpose of this article is to highlight what activities an academic has used to help senior engineering students demonstrate two of the 11 GAs required by ECSA that may help fellow academics, not to repeat mistakes, but rather achieve success in meeting the expectations of a national statutory body.

Firstly, the article provides a definition of the two attributes that are called engineering professionalism and engineering management. This helps to set the stage for selecting specific activities that may be used to help students demonstrate their acquisition. The study context, methodology, selected results and conclusions follow.

2. Two graduate attributes required by ECSA

Engineering professionalism (EP) calls on students to demonstrate critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within their own limits of competence [7]. Evidence of this includes case studies typical of engineering practice situations in which the graduate is likely to participate. Furthermore, acting professionally is inextricably linked with moral agency [8] that refers to our very moral fiber or character. Are we prone to twist the truth, tell a white lie, alter data to suit our research, copy work from others without acknowledging them, cheat on a test paper or evade taking responsibility for a mistake which we made. It can also be linked to ethical behavior, which includes key principles such as honesty, integrity, fairness, and concern for others [9]. Aspiring to these principles within the limits of our own competence relates to the quality of modesty. Subsequently, engineering professionalism may be defined as the demonstration of moral uprightness by individuals within the modest levels of their technical experience.

Engineering Management (EM) calls on students to demonstrate knowledge and understanding of engineering management principles and economic decision-making [7]. Basic techniques from economics, business management and project management are required. Professional engineering management has been defined as the skill of managing both engineers and other non-engineering employees in a practical, commercial and non-commercial environment [10]. Additional skills that are required by engineers to be successful in this type of environment include human resource, financial, operational, and marketing management. Managing individuals does not come naturally to many people but requires training and education. This is vital for many engineers who often form part of a larger team when working on long-term projects. Interaction, engagement and collaboration between different disciplines, and activities, is vital if these projects are to be successful.

3. Activities used by an academic in higher education

Engineering academics need to assess the formative development of engineering students by using diverse assessment techniques suited to the graduate attribute profiles [11]. Furthermore, an important feature of developing GAs is the design of the learning tasks [12]. These tasks, or activities, need to be aligned with the general definition or requirement of an attribute. When considering EP, such activities may include the completion of a patent application, business plan or application for registration with a statutory body. These were incorporated into three different practical assignments for a module called Technology Management III (TM3). When considering EM, such activities may include the creation of a Gantt chart and the design of a PowerPoint (PPT) presentation with audio that includes slides showing a marketing

poster, personal budget, and weekly study time schedule. These were incorporated into two different practical assignments for TM3. These five practical assignments are summarized in Table 1, where their learning outcomes are shown along with the relevant attribute to which they are tied.

A business plan (called P2 in TM3) needs a professional approach, knowledge, time and various analyses, predictions and assessments [13]. It requires individuals to report honestly on their past work experiences while being fair to their competition in mentioning them in a dignified way. This type of behaviour links well with the earlier definition given of EP that focuses on moral uprightness by individuals within the modest levels of their technical experience. This behaviour is also required when completing an application for registration with a statutory body.

The primary purpose of professional registration is to ensure that the public is protected from harmful or socially unacceptable practices on the part of service providers [14]. This relates to displaying concern for others while being honest in reporting accurately on one's own competencies. Also required is an honest report of one's current qualification and experience. Students were required to complete such an application as part of an assignment which was called P5.

Table 1: Two of the 11 graduate attributes with their definitions and learning outcomes for TM3

Graduate attribute	Requirement	Assignment required	Learning outcome/s
GA10 – Engineering Professionalism	Demonstrate critical awareness of the need to act **professionally and ethically** and to exercise judgment and take responsibility within own limits of competence.	P1 – Patent application	Explain the purpose of each section within a patent application form Complete a standard patent application form for a new invention
		P2 – Basic business plan	Create a basic business plan for a new restaurant that needs to be in DIRECT competition to a local well-known restaurant Design an organogram for this new business
		P5 – Application for professional registration	Identify the purpose of each section in the application and insert the correct information into it Review accepted voluntary associations in South Africa and list one on the application
GA11 – Engineering Management	Demonstrate knowledge and understanding of engineering management **principles** and economic decision-making.	P3 – PPT with audio	Design a marketing poster for this module and include it on a slide with AUDIO Design a monthly budget (table format) that could be used by students who enrol for this module and include it on another slide with AUDIO Design a weekly time / study schedule (table format) that covers all your current modules at CUT and include it on another slide with AUDIO

		P4 – Gantt Chart	Analyse an existing postgraduate Masters proposal for specific information Create a Gantt chart for the project using the gathered data / information

Filing a patent application requires specifications for an invention and a set of claims [15]. These claims can neither be exaggerated nor falsified which relates to moral uprightness requiring the student to demonstrate ethical behaviour in terms of honesty and integrity. Students were required to complete a basic patent application and submit it as their first practical assignment, called P1. The rubric for marking this assignment is shown in Figure 1. Rubrics for P2, P4 and P5 were also developed but are not shown in this paper due to space constraints.

The level of achievement in the rubric may catch one's eye, as they are listed as "not competent" or "competent". This indicates that the student needs to demonstrate specific skills that meets a given standard. In this case, the standard is defined by four criteria relating to the Background, Claims, Drawing and Abstract. The student has to master the skill of searching for art, or associated patents, that is relevant to his/her proposed invention. Additional skills include evaluating how the proposed invention is different from existing systems while explaining the operation of it using diagrams and text. Finally, the skill of compiling an abstract covering five key criteria is required to be demonstrated. Reducing academic dishonesty, in terms of limiting students who copy from fellow students, is mitigated by using SafeAssign, a feature available in BlackBoard™ that provides a similarity index for a submitted assignment. A similarity index of 10% or more is flagged and the assignment is graded with 20%, requiring the student to redo the assignment. This approach was also used with P2, the business plan assignment, which also forms part of EP.

Name	P1-ETM226-Rubric-V2
Description	This rubric applies to the Patent Application
Rubric Detail	

Levels of Achievement

Criteria	Not competent	Competent
Title and Background	**2 Points** Title, Student Number, Field and Related Art is missing, incomplete or not relevant	**4 Points** Title, Student Number, Field and Related Art is relevant with specific nouns used
Summary and Claims	**2 Points** Objectives OR Claims are missing / irrelevant / incomplete	**4 Points** Objectives are relevant to the invention in terms of WHAT is different from existing systems Claims are relevant in terms of WHAT can result from the invention
Drawing and Description	**2 Points** Drawing not labelled or description missing or incomplete	**4 Points** Drawing is labelled and 5 element numbers are visible Description is relevant and elements from the drawing are explained
Abstract	**3 Points** Abstract is incomplete or criteria or comments have not been removed OR File label is wrong or similarity score is more than 10%	**8 Points** Abstract includes background, purpose, methodology, number results and a specific recommendation

Figure 1: Rubric for the Patent Application, called P1

When considering EM, the creation of a Gantt chart was required in TM3, which calls on students to demonstrate the ability to identify important activities from a previously accepted Masters proposal and organize them chronologically on a limited time scale. This was part of a practical assignment called P4. Gantt charts are frequently used in project

management to provide a graphical illustration of a schedule that helps to plan, coordinate, and track specific activities in a project [16]. It thus has relevance to EM that includes basic techniques from business and project management.

Aspects of business management further includes studies such as marketing, accounting and schedule management [17]. Marketing (in the form of a poster), accounting (in the form of a budget) and scheduling (in the form of a weekly study time schedule) needed to feature as individual slides in a PPT presentation with audio which students had to design. This was required in a practical assignment called P3. Demonstration of technological literacy and communication skills were thus also evident, which may be linked to additional GAs. The inclusion of each student's voice helps to reduce academic dishonesty, as students need to explain each slide personally. The rubric used for marking this practical assignment is shown in Figure 2. Again, the words "not competent" and "competent" are visible with four specific criteria listed. The first four slides had to be complete in terms of student details. A poster design, advertising TM3 to future prospective students, needed to be included as slide five. Students had to first read an article on how to effectively design a marketing poster and then apply the theory in practice with their design. A personal monthly budget was then required to determine if students could correctly structure and formulate it. Finally, a weekly study time schedule had to be completed where the student would show time periods dedicated to study, to extra-curricular activities, to relaxation, etc.

Name	P3-ETM226-Rubric-V2
Description	This rubric applies to the PowerPoint Presentation
Rubric Detail	

Levels of Achievement

Criteria	Not competent	Competent
First 4 slides	**3 Points** Only 3 slides complete Audio does not play automatically Voice too soft No picture animation	**8 Points** Contact details visible Passport photo visible Picture animation present Distance on map visible All outcomes listed
Poster	**2 Points** Poster not captivating and colorful OR Contact details and module code not visible OR Price and purpose not visible	**4 Points** Module name, price and contact details CLEARLY visible on poster Colorful and captivating Logical and believable motivations Less text, more images
Budget	**2 Points** Budget unreasonable No income or total expenses visible	**4 Points** Income and expenses visible, but separate At least 6 items on the budget
Schedule	**2 Points** Schedule unreasonable No leisure time shown No module names or codes	**4 Points** 7 days of the week visible with allocated time slots Multiple modules shown on different days

Figure 2: Rubric for the PowerPoint Presentation, called P3

4. Study context

These two attributes, namely EP and EM, were required to be assessed in a compulsory exit-level module in a Bachelor in Engineering Technology (acronym BEngTech) degree in Electrical Engineering, offered at the Central University of Technology in South Africa. The module is termed Technology Management III (TM3). This degree is an NQF (National Qualifications Framework) Level 7 qualification that requires students to obtain a minimum of 360 credits (equates to 3600 notional hours over a three-year period). Approximately 150 undergraduate students register for this 14-credit module during their second year of study. The syllabus focuses on innovation strategies, entrepreneurship, ergonomics and four types of management (quality, operations, human resource, and project).

The module features hybrid learning where five online self-assessments are used to encourage student self-reflection and regular engagement with the course content, or theory work of the module (these contribute 25% to the course mark of the students). These are set and managed in Respondus (an offline software package for setting online assessments) and then uploaded to eThuto (the learning management system of the university built on the BlackBoard™ platform). Face-to-face lectures feature PPT presentations and active learning sessions involving case studies. These focus on true life stories of entrepreneurs, human resource departments and quality and operations managers. Lessons learned from these case studies include recipes for success and practices that can lead to disaster.

Five compulsory practical assignments need to be completed by the students which focus on the two main GAs, being EP and EM (these contribute 35% to the course mark, representing the practical work of the module). These assignments are submitted online and graded in eThuto using predefined rubrics. All course content is posted on eThuto, where students can also monitor their progress through means of the grade center. Regular announcements and the weekly use of the calendar helps students to stay engaged and informed of pending deadlines.

A main assessment (40% contribution to the course mark) is usually scheduled during Week 9 of the 13-week semester, with a main examination during Weeks 15-18. The final grade of the students is calculated using 50% of the examination mark and 50% of the course mark. However, students need to obtain a minimum mark of 50% for each of the two GAs, in order to gain entry into this main examination.

5. Methodology

A descriptive case study is used which aims to provide a description of a phenomenon (activities used to help students demonstrate the acquisition of two GAs) within a given context (a higher education qualification in engineering). A descriptive case study has further been defined as a real-world situation facing people or groups and how they addressed it [18]. In this study, the real-world situation is how to integrate and assess specific GAs into an engineering curriculum and how this was addressed by an engineering academic who used specific activities aligned to the definition of the attributes.

Quantitative data, in the form of student final grades for the two attributes, are contrasted using a scatter plot in order to determine the percentage of students who were able to successfully demonstrate their acquisition. A linear relationship further enables two situations to be compared [19]. In this case, the two attributes are compared in terms of student difficulty. Did students perform well on one attribute, and poorly on the other? Or do students generally perform equally well on both GAs? The sample size is 371 senior engineering students enrolled over a 2-year period covering the COVID-19 pandemic (2021) and the post-pandemic era (2022). Student final grades were obtained from eThuto where all practical assignments needed to be submitted and where they were finally graded online by the academic in this module.

6. Selected results of the assignments

Figure 3 shows the final grades of students for the two GAs in 2021, while Figure 4 presents the results for 2022. A higher percentage of students obtained a distinction for EM (98 students in 2021 and 87 students in 2022), as compared to EP (23 students in 2021 and 38 students in 2022). This required more than 75% which forms part of the “competent” indicator. Some of the students struggled to complete the patent application and business plan required for EP, as they were completely new concepts to them. The Gannt chart (P4) and PPT presentation (P3) was easily completed by many students who demonstrated good computer literacy skills that contributed to EM.

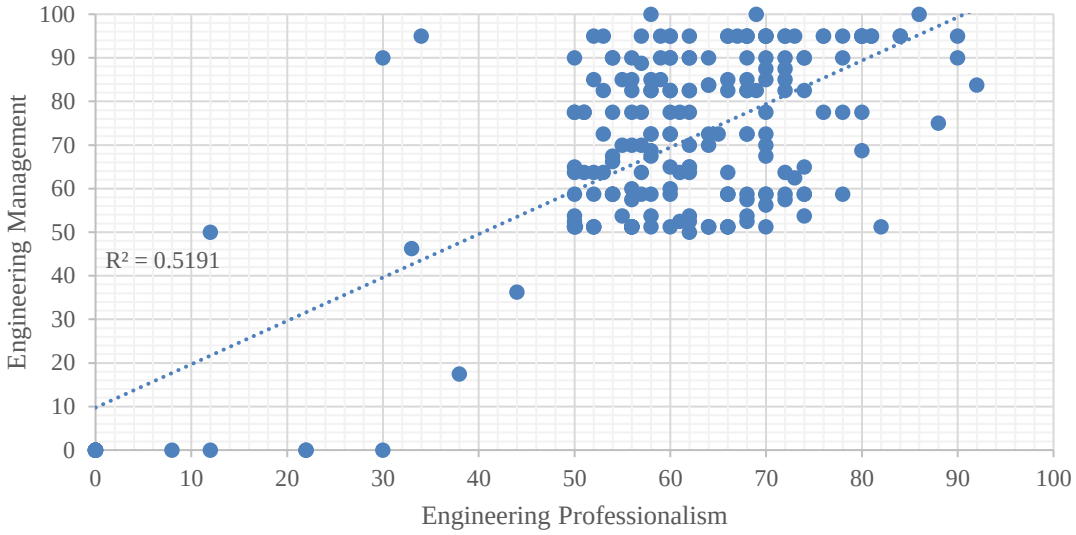

Figure 3: 2021 final grades for 200 students

A moderate strong positive relationship (0,519 in 2021) was determined between the two GAs that suggest that if students could successfully engage with the learning outcomes of EM, then they could also do so with EP. Similar results were found for 2022 (r^2=0,646). This further suggests that the activities were neither too challenging nor complex for the students to complete. The average grade by students for EM was 69% and the average grade for EP was 60%.

However, when comparing P1 and P2 for all 371 students in EP (see Figure 5), it becomes evident that the business plan (P2) was more difficult to complete than the patent application (P1). Completing a patent application is applicable to many fields of study, including science, technology and engineering, while a business plan is more applicable to the field of management. This suggests that engineering students need more exposure to fundamental business management principles if they are to become effective entrepreneurs or managers within the workspace. Obtaining student feedback in this regard may also help in determining further interventions to better assist students to effectively demonstrate the acquisition of this important attribute.

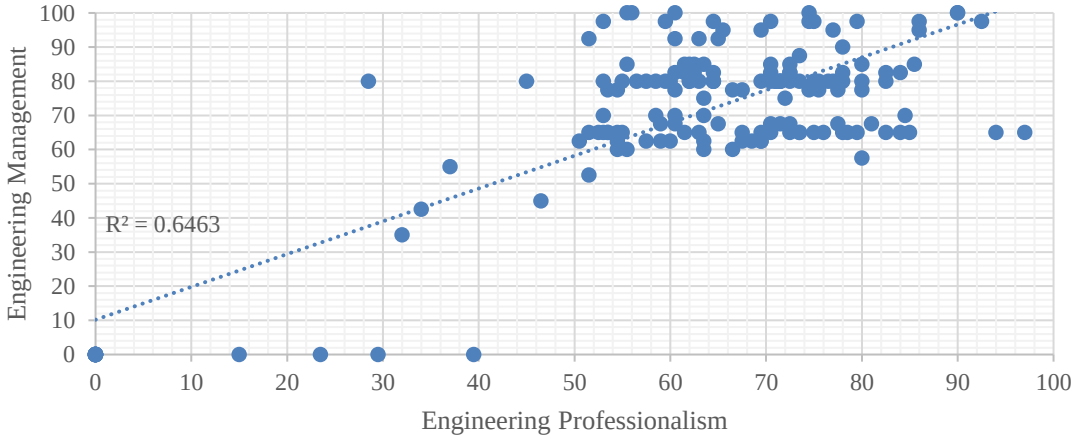

Figure 4: 2022 final grades for 171 students

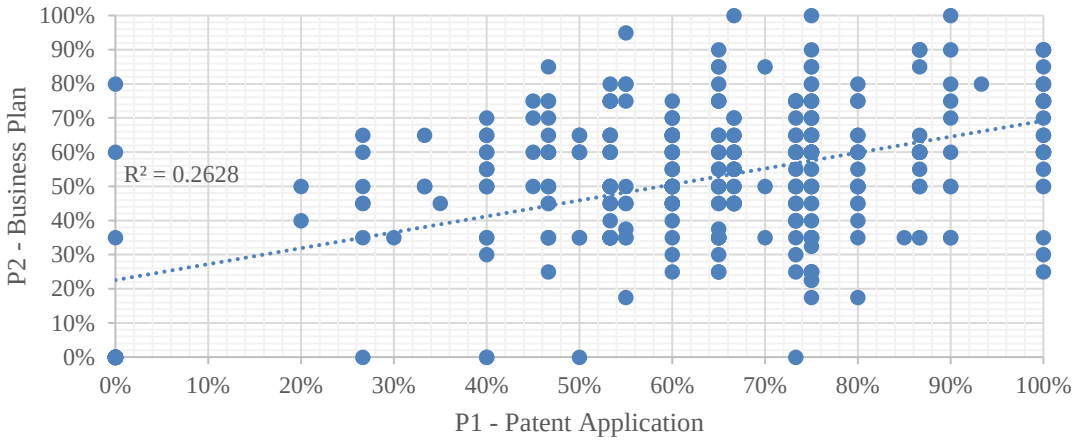

Figure 5: P1 versus P2 for 2021 and 2022 (n=371)

7. Conclusions

The purpose of this article was to highlight what activities an academic used to help senior engineering students demonstrate two of the 11 GAs required by ECSA in South Africa that may help fellow academics, not to repeat mistakes, but rather achieve success in meeting the expectations of a national statutory body. The qualification was successfully accredited by ECSA in 2022, where exit-level modules (or final year modules) featuring GAs at the advanced level were scrutinized. This testified to the validity of the approach taken with regard to EP, including its activities. EM will only be considered with the next accreditation visit, as it is a relatively new addition to the list of attributes.

The final grades of students for the practical work done in this module further indicate that the assignments were neither too challenging nor too complex. The average grade for both assignments over a 2-year period (2021-2022) for 371 students was 65%, with an average standard deviation of 22,2. The average pass rate for these two assignments was 89%.

The study was limited to only two GAs within one module. Only one experience from one academic has been shared. Many other universities exist where academics may have different experiences or thoughts in this regard. It is recommended to share them also in the public domain. Furthermore, the other nine GAs have not been reported on in this article. The learned experiences of academics who have integrated and assessed these attributes in their respective modules should also be shared in the public domain. This will increase and enrich the current literature in this regard, exposing fellow academics to a wealth of experiences that are either good or bad.

It is recommended that academics continue to share their experiences with regard to assessing GAs, as this will continue to contribute to the dialogue and help guide fellow academics in meeting this ongoing challenge. It will also help fellow academics to avoid repeating the mistakes of others, but rather achieve success in meeting the expectations of national statutory bodies around the globe.

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