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RESEARCH ARTICLE:

Assessing the Impact of Undergraduate Research on Graduate Attributes Development: A Case Study of DUT Civil Engineering Students

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Abstract

Engineering graduates are expected to demonstrate competence after their engineering programmes in the form of graduate attributes (GAs) prescribed by the Engineering Council of South Africa (ECSA). It has, however, been challenging to develop and assess these attributes, especially using conventional assessment or examination methods, just as on the global scale. Nevertheless, studies have demonstrated that undergraduate research enables students to develop independent critical skills, as they do in graduate studies, by identifying a problem that needs to be solved. Undergraduate research has not been widely explored as a tool in developing and assessing GAs in engineering students. This study examined the impact of undergraduate research in engineering student ECSA GAs development and assessment using a case study of civil engineering diploma students. Therefore, using purposeful quantitative sampling methods, first-year and second-year diploma students were interviewed on their experience with newly introduced undergraduate research. Observations of the students' responses indicated that students' understanding, and views of GAs do improve from the first year to the second year due to continuous exposure to research. A conceptual model for assessing and developing GAs among engineering students is proposed in this study. This conceptual framework can assist in the further development of strategies in the implementation of undergraduate research at universities of technology.

Keywords: *conceptual framework; ECSA graduate attributes; engineering graduates; undergraduate research*

Introduction

For many years, curricula in engineering have been heavily influenced globally by the requirements of accreditation by professional institutions (Varnava and Webb 2021). Accreditation guidelines have prescribed minimum contents of sub-disciplines, admissions standards, and even contact hours. This influence has now shifted to output standards (Fry *et al.*, 2021). These output standards focus on the graduate skills set which is embedded in the graduate attributes prescribed by accrediting professional institutions.

Graduate Attributes (GAs) are a set of well-defined skills, values, attitudes and knowledge that students must have developed by the end of their degree programmes (Hill and Walkington, 2016; Bitzer and Withering, 2020). Since each student is required to demonstrate competency in each GA in the workplace or industry after completing their engineering programs, the assessment and development of GAs has become essential for engineering students. The Engineering Council of South Africa (ECSA, 2019) lays out this requirement in their qualification unit standards. These GAs include problem solving; application of scientific and engineering knowledge; engineering design; investigations; experiments and data analysis; engineering methods; skills and tools, including information technology; professional and technical communication; sustainability and impact of engineering activity; individual, team and

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multidisciplinary working; independent learning ability; and engineering professionalism (ECSA, 2016). Since the inception of the Higher Education Qualifications Sub-Framework (HEQSF) civil engineering diploma in technology programme in January 2017 to August 2020, there were a total of 10 GAs prescribed by the ECSA. In September 2020, the ECSA introduced an 11th GA for development and assessment in all diploma in technology programmes (ECSA, 2020). Hence, the civil engineering diploma in technology programme still applies the ten (10) GAs prescribed upon inception. This paper refers to the development and demonstration through assessment of the ten (10) GAs competency indicator knowledge at the exit level of the civil engineering diploma in technology programme.

All engineering graduates, be they at diploma or bachelor level, are expected to have fulfilled these ECSA GA requirements, since they form part of the programme sub-minimum criteria necessary for the qualification to be awarded. ECSA is not, however, specific about the methods of assessing these GAs, but advised that the "providers of programmes shall, in the quality assurance process, demonstrate that an effective integrated assessment strategy is used" (ECSA, 2016). Thus, difficulties have been experienced by lecturers and the faculties of engineering in the process of developing and assessing these attributes, especially using the conventional assessment or examination methods available (Kensington-Miller *et al.*, 2018; Swart, 2018). Yet, undergraduate research has not been widely explored as a tool in developing and assessing graduate attributes in engineering students.

In Africa, higher education is influenced by many factors. Among these factors are the history of colonialism, politics, poverty, global inequalities, and low research outputs (Bitzer and Withering, 2020). Accreditation boards and the industry have tried to address these by introducing GAs that the higher education institutions (HEIs) now focus on. GAs are a framework of skills, attitudes, principles, and knowledge that HEI graduates should develop (Hill and Walkington, 2016; Bitzer and Withering, 2020). The South African HEIs face a challenge to deliver graduates who are critical and engaged citizens (Bawa, 2014; Chetty and Pather, 2016). These graduates need to be able to contribute to the economy as well as merge into international standards.

According to Swart (2018), not only is it challenging to assess GAs, but the challenge is also to identify or understand them for both academics and students in higher education. The challenge in assessment is highly significant for undergraduate civil engineering education. In this discipline, the students must acquire a set of well-defined competency indicator knowledge, which needs to be assessed appropriately (Das, 2020). However, Angel *et al.* (2022) suggest the possibility of assessing multiple competencies required from a graduate through the final-year design project or capstone project. In Tian (2007), deep learning, as provided by specific questions assigned to students in advance so they can prepare in their own time, is said to focus on critical learning skills to assess the ability of students to resolve problems themselves. This gives students time to learn the concepts, understand, and apply them. Globally, the concept of undergraduate research has been around for long (McGoldrick, 2007). In Africa, the late start in the race to setting up and obtaining universities has resulted in delay in the implementation of undergraduate research activities (Kizza, 2011; Bovijn *et al.*, 2017). Coupled with students having disadvantaged backgrounds, generally attracted by the Universities of Technology, undergraduate research is still lagging.

According to the Council for Undergraduate Research (2021), undergraduate research is "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline". Undergraduate students, especially first-year students, are likely to be novices to the concept of research. However, developing and maintaining undergraduate research programmes not only benefit students, but also faculty mentors and the university (Petrella and Jung, 2008), and this programme supports an important set of student outcomes related to cognitive, career, and skills development. In South Africa, undergraduate research has been on the rise among students from the faculty of health sciences (Bovijn *et al.*, 2017; Vahed and Cruickshank, 2018; Marais *et al.*, 2019; and Mahomed, Ross and

Van Wyk, 2021), and this has been related to the fact that research skills are a necessity for the survival and recognition of any health training institution (Munabi, Katabira and Konde-Lule, 2006; and Mahomed *et al.*, 2021). In the context of civil engineering, with the focus on sustainable infrastructure and engineering, research skills have become a need, as there remains a gap between the encapsulation of development of different ideas to solving engineering problems versus the practical understanding of the feasibility of each idea. Hence, the need for undergraduate research skills.

An undergraduate research experience must integrate strong mentoring, a link to participants' coursework, and a more general understanding of the nature of scientific research, including the collaborative nature of the scientific community. Various limitations have, however, been identified with the incorporation of research into undergraduate study under these categories: curriculum – time and space; research support and capacity – inadequate infrastructures and supervisor; and student competency (Marais *et al.*, 2019). Nevertheless, even with the impact systems for undergraduate research, its benefits cannot be overemphasised if the limitations are properly addressed or managed. Overall, there exists a relationship between GAs and the qualities of undergraduate research (Table 1). From Table 1, the quality of undergraduate research was cross-referenced with the GA attributes. It is evident that the majority of the quality of the undergraduate research fits into the GA. Looking closely to the GA1 definition according to ECSA, it is noted that the word 'apply' expresses responsibility which is one of the qualities of undergraduate research. Similarly, 'systematically diagnose' and 'solve well-defined' translate to undergraduate research qualities such as analysis and patience, and thoroughness, respectively. These undergraduate research qualities can be seen across all the GAs (Table 1) and GA3 and GA10 are ranked the highest with GA6, GA7 and GA9 ranking the lowest. GA3 and GA10 speak of the core of engineering values.

This research aimed to evaluate whether undergraduate research can help students in developing and creating awareness surrounding graduate attributes. The students were consulted by means of a questionnaire survey within this process to gauge their viewpoints on the matter. Moreover, their opinions were sought on how to improve these methods. This study assesses the impact of undergraduate research on engineering student GAs development using a case study of civil engineering diploma students at the Durban University of Technology (DUT).

Table 1: Cross-reference table of quality of Undergraduate Research in relation to GA (Adapted from: Hensel, 2012; ECSA, 2016)

Graduate Attribute		**Graduate Attribute Definition** (ECSA, 2016)	**Quality of Undergraduate Research**											**Rating Count**
			Responsibility	**Persistence**	**Synthesis**	**Analysis**	**Thoroughness**	**Teamwork**	**Leadership**	**Commitment**	**Patience**	**Perspective-Taking**	**Ethical Behaviour**	
1.	Problem solving	Apply engineering principles to systematically diagnose and solve well-defined engineering problems	X			X	X				X			4
2.	Application of scientific and engineering knowledge	Apply knowledge of mathematics, natural science, and engineering sciences to applied engineering procedures, processes, systems and methodologies to solve well-defined engineering problems.	X		X	X						X		4
3.	Engineering Design	Perform procedural design of components, systems, works, products, or processes to meet requirements, normally within applicable standards, codes of practice and legislation.	X		X	X		X	X		X		X	7
4.	Investigation	Conduct investigations of well-defined problems through locating and searching relevant codes and catalogues, conducting standard tests, experiments, and measurements.	X	X			X				X		X	5
5.	Engineering methods, skills, and tools, including Information Technology	Use appropriate techniques, resources, and modern engineering tools including information technology for the solution of well-defined engineering problems, with an awareness of the limitations, restrictions, premises, assumptions, and constraints.	X		X	X				X				4
6.	Professional and Technical Communication	Communicate effectively, both orally and in writing within an engineering context.	X				X					X		3
7.	Impact of Engineering Activity	Demonstrate knowledge and understanding of the impact of engineering activity on the society, economy, industrial and physical environment, and address issues by defined procedures.	X			X						X		3
8.	Individual, Team and Multidisciplinary Working	Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member and leader in a technical team and to manage projects	X					X	X	X				4
9.	Independent Learning Ability	Engage in independent and life-long learning through well-developed learning skills.	X	X							X			3
10.	Engineering Professionalism	Understand and commit to professional ethics, responsibilities, and norms of engineering technical practice.	X			X	X	X	X	X			X	7

Theoretical Framework

Kambil, Friesen and Sundaram (1999) propose a theory on the phenomenon of co-creation between the producer and the customer. The co-creation theory is described as "the participation of consumers along with producers in the creation of value in the marketplace" (Kambil *et al.*, 1999; Zwass, 2010). Additionally, in co-creation, there is a shared, collaborative, concurrent, peer-like process of producing new value, both materially and symbolically (Galvagno and Dalli, 2014). This theoretical concept has found application in various fields different from the initial concept, fields such as: creating public value (Bryson *et al.*, 2017), research (Greenhalgh *et al.*, 2016), and education (Dollinger, Lodge and Coates, 2018; Bovill, 2020; Könings *et al.*, 2021). Zwass (2010) argues and proposes the systematic process of co-creation as described in Figure 1. The focus of this study, nevertheless, is not on customers' contribution to producer creation, but rather on how undergraduate research can support and facilitate the development of graduate attributes.

Zwass (2010) further asserts the value of co-creation into various components. These four components of co-creation include co-creators (agents collectively motivated to work on a common task), process (policies, governance, incentives, and IT support), task (task characteristics requirements), and co-created value (values). Conceptualising the co-creation theory components to this study, the co-creators include the lecturers, the technicians, the industrial experts, ECSA, and the undergraduate students. The process component speaks to the use of undergraduate research activities in achieving the task, where the task component is the graduate attributes which is a requirement to be accomplished. The co-created value will be in terms of innovative outputs, research publications, and graduate attributes.

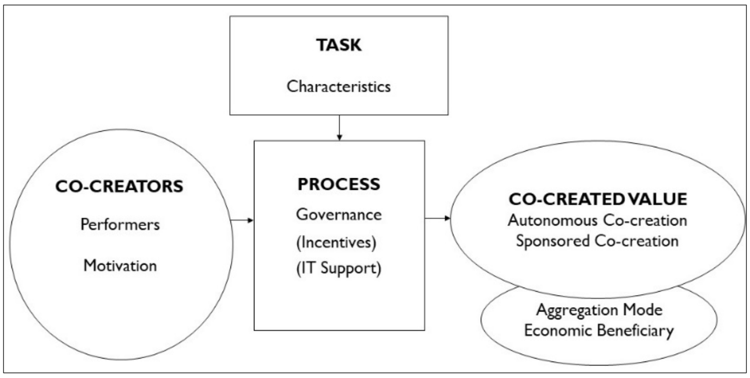

Figure 1: Taxonomic framework of value co-creation (Zwass, 2010)

Furthermore, considering the potential of undergraduate research as a method of assessing and developing graduate attributes in engineering students, the communities of practice theory linked to the co-creation theory should provide good leverage. Communities of practice, according to Wenger (2011) are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". This theory has also found a wide application in business, organisational design, government, education, and development projects, among others. As a result, it is a foundation on knowing and learning that inform efforts to create learning systems in various sectors and at various levels of scale, from local communities to single organisations, partnerships, cities, regions, and the entire world (Wenger, 2011).

Overall, the development and assessment of GAs has been a difficult task for engineering lecturers and students. The DUT Civil Engineering, Midlands, has resolved to embed GA assessments within assignments, projects, and laboratory practicals. This way, the students are exposed to hypothetical or real engineering situations and are asked to research the problems and provide solutions. It is believed that course-based undergraduate research experiences have the potential to give all students, rather than only a select few, the opportunity to engage in research (Bangera and Brownell, 2014). This, however, results in complaints by students due to the volume of work and stringent etiquettes under which these assessments are performed. It is important to understand the students' perception of the GAs to assess if the methods employed are useful or how could they be improved (Bitzer and Withering, 2020).

Methods and Tools

A quantitative approach using questionnaires defined by sample size specifying a given margin of error, which justified the population size of the total students and provide a confidence interval of judgement (Gray, 2013) was used in this study. Questionnaires were administered via Microsoft Forms (MS Forms), as this tool was familiar to students and ensured safety during the Covid-19 pandemic. MS Forms was set to not collect the names and e-mail addresses of the students, thus maintaining anonymity and confidentiality of the student participants. This questionnaire was designed to have three sections: the first section classified the demographics of the students, while the second section looked at the relationship between undergraduate research and Graduate Attributes, and the third section enquired about personal reflections and experiences on undergraduate research.

Both Year 1 [Semester 1 {S1} and Semester 2 {S2}] and Year 2 [Semester 3 {S3} and Semester 4 {S4}] students of the two-year HEQSF Diploma in Engineering Technology: Civil Engineering (DICVE1) programme were targeted for the survey. This programme is only offered in the Department of Civil Engineering Midlands (Indumiso Campus). It is important to hear from different groups of students; therefore, no preselection was done. Overall, a sample size of 205 was expected to complete the questionnaire based on a marginal error of 5% and a 90% confidence interval. Students who are registered for Construction Management, Bachelor of Technology in Civil Engineering, or any other qualifications associated with the Civil Engineering discipline within, or outside DUT were excluded from this study. Requests to participate in the study were sent to all classes in Microsoft Teams as well as the Civil Engineering Midlands student group on Edmodo. Considering this study with a target population of 839, the use of a simple random sampling method was used, because this investigation involves a category of the target population and its accuracy of representation (Gray, 2013).

Reliability and validity, the concepts of measurement criteria of any type of measure (Singh, 2017), are central to the value of any data-gathering procedure. Validity is defined as the extent to which a concept is accurately measured in a quantitative study (Heale and Twycross, 2015). According to Sürücü (2020), reliability is an indicator of the stability of the measured values obtained in repeated measurements under the same circumstances using the same measuring instrument. Thus, in this study, the questionnaire was constructed to ensure ease of use and the reliability of the responses was considered. To ensure reliability, the questionnaire was piloted to twenty (20) students to check for double-barrelled questions, and the level to which the items are established in orderly connection with one another in the questionnaire was ascertained.

The data collected were statistically analysed using the Statistical Product and Service Solutions (SPSS) package. Standard descriptive statistics were reported in terms of mean and standard deviation for numerical variables for trichotomous questions, and frequency count (%) for categorical variables, for example, demographic of respondents. In addition, a cross-tabulation with chi-square analysis was conducted to establish the relationship on how undergraduate research impacts engineering student GA development and assessment. All etiquettes, as advised by the DUT Institutional Research Ethics Committee (IREC) as well as the DUT gatekeeper were followed during and post this study. The students who participated in the study were informed of the purpose of the study. Participation in the study was voluntary and thus only the researchers had access to raw data. Privacy was always maintained and all information that was gathered was treated as confidential. The participants were allowed to withdraw from the study at any stage. No monetary (or otherwise) gain was to be obtained by participating in this study.

Results and Discussion

The survey was completed by 112 diploma students of the Department of Civil Engineering Midlands. Table 2 shows the categories of gender, age, and study level. Approximately 45% of the respondents were female, 54.5% were male, and only 0.95% non-binary. Baguant (2021) reports that there is an underlying gender disparity in civil engineering training in higher education where there are more males than females. The majority of the students were between the ages of 19–24 (69.6%), only 0.9% were above 35 years old, and the rest were between the ages 15–18 and 25–34. This is expected in a country where 63.3% of the population are constituted of individuals in the 15–34 age category (Stats, 2020). In terms of study level, the majority of the students that responded to the survey are in the final semester of study (S4) at 50.9%.

Table 2: Demographic description of the student respondents

Description	Percentage
Gender	
Male	54.5
Female	44.6
Non-Binary	0.9
Age (years)	
15-18	12.5
19-24	69.6
25-34	17.0
35/Above	0.9
Diploma (semesters)	
Short Course	1.8
S1	14.3
S2	24.1
S3	8.9
S4	50.9

Figure 2 shows the responses of the students with regard to the subject that introduced or introduces them to research, while Table 3 provides supplementary information for Figure 2. Subject G, which is a Year 1 module, deals with technical communication and the basics of research. Above 50% of all participants agreed that subject G introduced or introduces them to research: this shows the impact of this subject on the students. This is so because in subject G, students demonstrate the GAs development through project-based assignments, although the competency indicator is not assessed in subject G, since this subject is not at the exit level. Typical assignments given in this module cut across civil engineering sub-disciplines using different aspects of research (for instance, methodology, data collection, results analysis, and others). This subject is followed by Subjects B and D, both in Year 2 (exit level). Subject B and C, being S3 and S4 subjects, respectively, with management of civil engineering contracts and specialised area in civil engineering, students demonstrated competency through GAs assessment (conventional assessment and project-based assignment). Gratchev and Jeng (2018) state that project-based assignments provide students with opportunities to understand the course material better, gain more practical experience, and learn how to apply theory to practice. Overall, more can be achieved if proper project-based assessments are introduced in all subjects or in the different subjects that establish the various areas of specialisation in civil engineering disciplines.

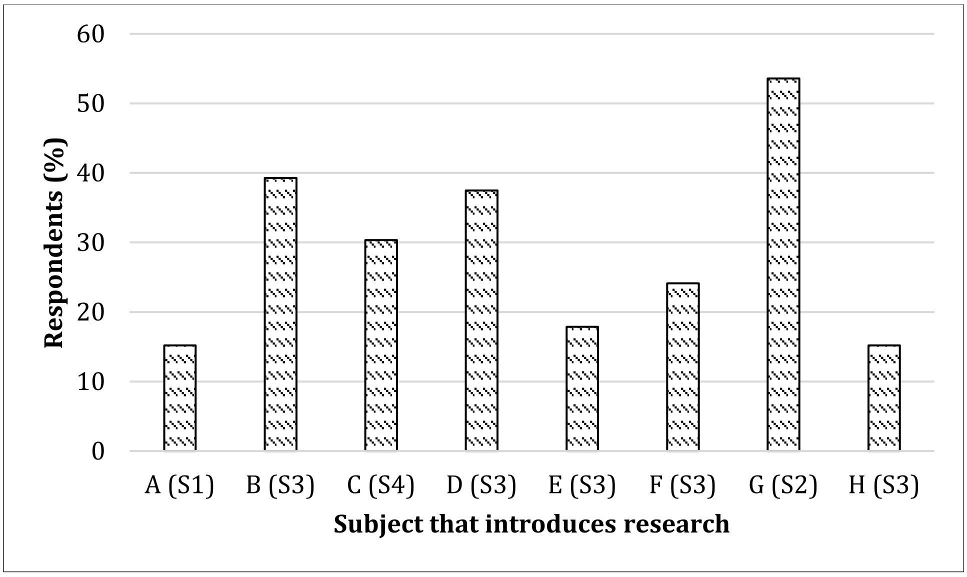

Figure 2: Subject that introduced students to research where letters represent different subjects

Table 3: Description of subjects that introduced students to research

Subject	Year	Assignment/Practical/Project	GAs Competency Development	GAs Competency Assessment
A	1	Laboratory Practical	1, 2, 5 & 9	-
B	2	Assignment	5, 9 & 10	10
C	2	Project	1, 2, 3, 4, 5, 6, 7 & 9	1, 2, 3, 4, 5, 6, 7 & 9
D	2	Assignment/Laboratory Practical	1, 2, 4, 5, 8 & 9	-
E	2	Laboratory Practical	1, 2, 5 & 9	1 & 9
F	2	Assignment/Laboratory Practical	1, 2, 3, 5, 6, 8 & 9	2 & 8
G	1	Assignment	6, 9 & 10	-
H	2	Assignment	1,2 & 3	3

Based on the GA range statements, the following questions were asked to the students for the respective GAs:

GA1 "Has research helped you in engineering problem identification and solving?"
GA2 "Has research helped you in application of scientific and engineering knowledge?"
GA3 "Has research helped you in investigations, experiments, and data analysis?"
GA4 "Has research helped you in engineering design?"
GA5 "Has research helped you in understanding and applying engineering methods, skills and tools, including information technology?"
GA6 "Has research helped you in understanding professional and technical communication?"
GA7 "Has research helped you in understanding sustainability and impact of engineering activity?"
GA8 "Has research helped you in individual, team and multidisciplinary working?"
GA9 "Has research helped you in independent learning?" and
GA10 "Has research helped you in understanding and applying engineering professionalism?"

Figure 3 shows responses from Year 1(a) and Year 2(b) students with regard to GAs. GAs are embedded in assessments as shown in Table 3 and are developed in Year 1 (developmental phase) and assessed in Year 2 (exit-level assessment phase) across different modules of the DICVE1 programme especially in the design project (Angel *et al.*, 2022). There is a clear difference between the responses of Year 1 and Year 2, with Year 2 mostly replying with "yes" in most GA questions. This is expected, as Year 1 students are still only introduced to GAs through the "development phase". The agreement between the two levels (that is, Year 1 and 2) is with GA 1 (Problem Solving) only. Furthermore, it is worthy of noting that in GA 3 (Engineering Design) and GA 10 (Engineering Professionalism*)* in Year 2, students agreed that research has helped them with the understanding of engineering design and engineering professionalism (Hill and Walkington, 2016). This, however, translates to the research quality such as responsibility, synthesis, analysis, and ethical behaviour as depicted in Table 1 and also correlates with the results of the rating presented in Table 1.

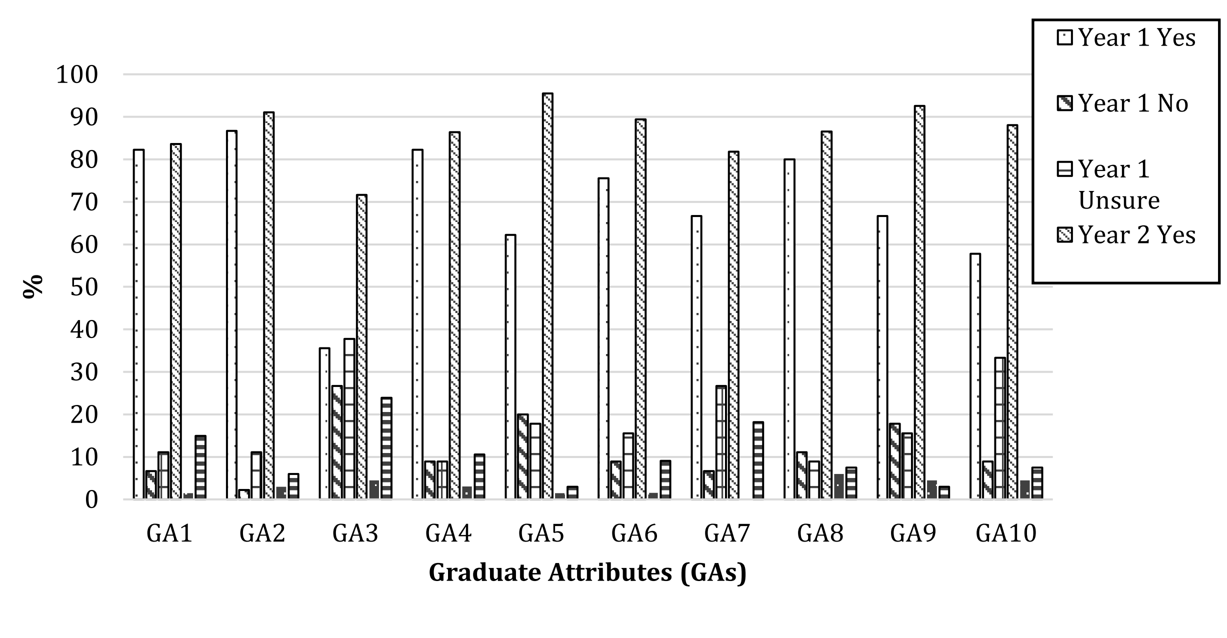

Figure 3: Students' responses on undergraduate research-graduate attributes-related questions for Year 1 and Year 2

The use of test of independence chi-square statistical tool was employed to test the hypothesis relating to student characteristics and undergraduate research – graduate attribute-related questions. Thus, the null and alternative hypotheses for the testing were:

- H_o: "Student characteristics in terms of diploma level and their opinion of undergraduate research are independent of each other."
- H_i: "Null hypothesis is not true"

The expected cell frequencies were compared with the observed cell frequencies using the test chi-square, as estimated using equation 1 below.

$$X^2 = \sum \frac{(O_{ij} - E_j)^2}{E_{ij}} \; Equation\ 1$$

where: X^2= chi-square; O_{ij} = observed frequency of the cell in the ith row and jth column; and E_{ij}= expected frequency of the cell in the ith row and jth column

The calculated chi-square results were compared with the critical chi-square value (Table 4) with (r-1) x (c-1) degree of freedom to decide on the acceptance or rejection of the null hypothesis (Kothari, 2004; Pandis, 2016). The decision rule used in Table 4 is as follows: "If $\chi^2_{tab} > \chi^2_{cal}$, accept H_o, otherwise reject".

Table 4: The calculated chi-square result (χ^2_{cal}) where the degree of freedom (df) is 8 and therefore the expected χ^2_{tab}=15.51

Graduate Attribute (with Dip level)		χ^2 cal
GA1	(Has research helped you in engineering problem identification and solving?)	21.847
GA2	(Has research helped you in application of scientific and engineering knowledge?)	19.522
GA4	(Has research helped you in investigations, experiments, and data analysis?)	14.085
GA3	(Has research helped you in engineering design)	23.769
GA5	(Has research helped you in understanding and applying engineering methods, skills, and tools, including information technology?)	24.170
GA6	(Has research helped you in understanding professional and technical communication?)	6.960
GA7	(Has research helped you in understanding sustainability and impact of engineering activity?)	15.969
GA8	(Has research helped you in individual, team, and multidisciplinary working?)	11.781
GA9	(Has research helped you in independent learning?)	29.928
GA10	(Has research helped you in understanding and applying engineering professionalism?)	38.341

In a cross-classification analysis of students' diploma levels and their opinion of undergraduate research, the results are presented in Table 4. Considering a 5% level of significance, the chi-square value is 15.51. However, the calculated chi-square values for GA1, GA2, GA3, GA5, GA7, GA9, and GA10 were larger than the critical values (Kothari, 2004), thus indicating that there is a relationship between the diploma level and student opinion of undergraduate research. However, the null hypothesis is accepted for GA4, GA6, and GA8 only. This implies that for the rest of the GAs, the student characteristics in terms of diploma level and their opinion of undergraduate research are independent or not associated with one another. It is worthy to note that gender and age characteristics of the students do not influence their opinion of undergraduate research.

Approximately 71% of the students aim to enrol in postgraduate education, as shown in Table 5, 7% have changed their plans away from postgraduate education, and the remainder has no intention of enrolling in postgraduate education. The scepticism witnessed in the 29% that have not solidified their plans for postgraduate education can be due to several reasons including research being a “fear” rather than a learning and a knowledge contributing factor. This emphasises the need to include a research module in the HEQSF-aligned diploma programme. In addition, Table 6 presents further details of plan for the 71% of students aiming to enrol for postgraduate education. Students reported their plans for post-diploma education; a majority (37%) of the students planned to further their education up to bachelor’s degree, followed by 27% up to the postgraduate diploma and the rest considering up to master’s and PhD level. This implies that out of 100 students only 26 would probably register for a master’s degree or continue to the PhD level, without putting into consideration other factors that contribute to the dropout rate (Pocock, 2012; Murray, 2014).

Table 5: How did the research experience influence your plan for postgraduate education?

Responses	Percent (%)
Had a plan for postgraduate education that has not changed	33.6
Confirmation of postgraduate education consideration	24.3
Research has changed prior plan in direction of postgraduate education	13.1
Research has changed prior plan in direction away from postgraduate education	6.5
Still no plans for postgraduate education	22.4

Table 6: Plans for engineering education beyond the undergraduate diploma

Responses	Percent (%)
Postgraduate Diploma	26.63
Bachelor’s Degree	37.4
Masters	13.1
PhD level	23.2

Forty-nine (49) students provided advice on how they think undergraduate research can be improved for the students' gain. Most of these students (45%) were in S4 level, followed by S2 level (31%), and the least were in S3 level (6%). While some students stated that they saw nothing that needed improvement, others suggested, "*Improving researching resources*"; "*Continuous Guidance from foundation phase up*"; "*Individual projects rather than group projects to enhance individual growth*"; "*Practical/fieldwork*"; "*More research*"; "*Supervision*"; "*Foundation level module that focuses on research*"; "*Increased time on deadlines*"; and "*More problem solving*". These thoughts align with some of the suggestions by Camara and Toure (2010) and Kizza (2011) to improve the quality of research at African universities.

Figure 4 shows the students' responses to the question "Select which of research experience you gained and understood during Undergraduate research experience". Based on this figure, students have mostly gained an understanding of the research process (63%), self-confidence (49%), and ability to analyse data (48%). More effort needs to be put towards helping students understand the literature review and data gathering processes.

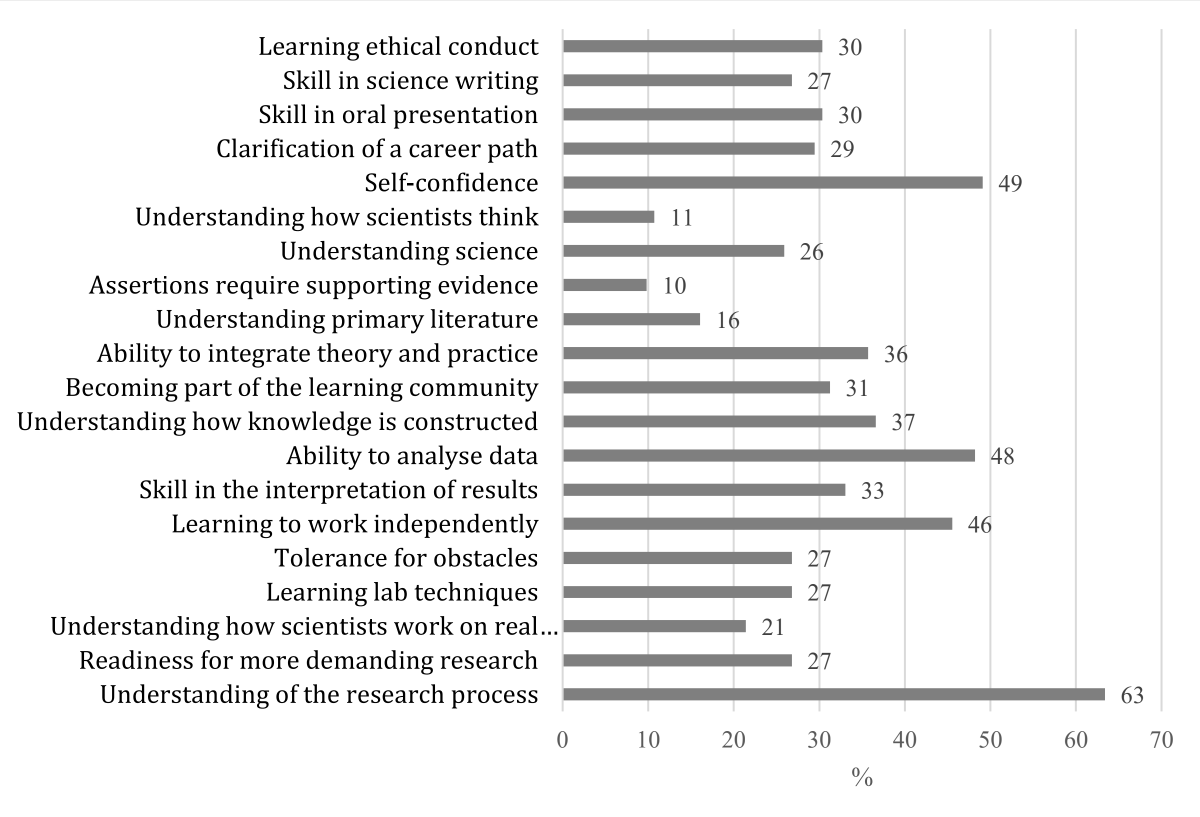

Figure 4: "Select which of research experience you gained and understood during undergraduate research experience"

Proposed Conceptual Framework

The model for developing and assessing GAs among engineering students can be conceptualised as illustrated in Figure 5. This model is an adjustment of Figure 1, which is the taxonomic framework of value of co-creation by Zwass (2010). This model illustrates the *domain* (university, classroom, and subject), where variables such as the lecturers, technicians, industrial experts as external moderators; and ECSA interact with the undergraduate students.

The lecturers and technicians as the *co-creators* initiate the knowledge-sharing platforms through setting of assignments, tests, projects, or practicals (*process/task*) for GA assessment. The industrial experts provide the working environment and mentorship that expose the student to the real-life practice in engineering while researching real-life problems, this is the current practice for the design project; while ECSA provides the framework against which assessment and development of GAs exists. Through assignments, tests, projects, or practicals, various graduate attributes are developed; however, *limitations* such as time constraints and workload on students and lecturers still exist within the *domain*. These limitations can be leveraged with the concept of undergraduate research activities complementing the conventional assessments as most of its qualities are related to GAs.

Furthermore, the participants that serve the key role as the *co-creators* and the *process/task* which are the assignments, tests, projects, or practicals can be consolidated to undergraduate research, which can be used to evaluate the GAs. The undergraduate research provides the student with advantages from teamwork, research mentorship, and professionalism. On the other hand, the undergraduate students are also co-creators as they engage with undergraduate research (*process*) and in turn *create knowledge*. The result of the process leads to various outcomes (*co-created values*) such as graduate attributes, publications, business ideas, and innovations that will benefit the universities and the students can be expected. Overall, the framework is looped with *continuity* from the *co-creators* to *co-created values* as undergraduate research can produce other research areas. This model can be adapted by other universities of technology within South Africa for their own specific needs and resources.

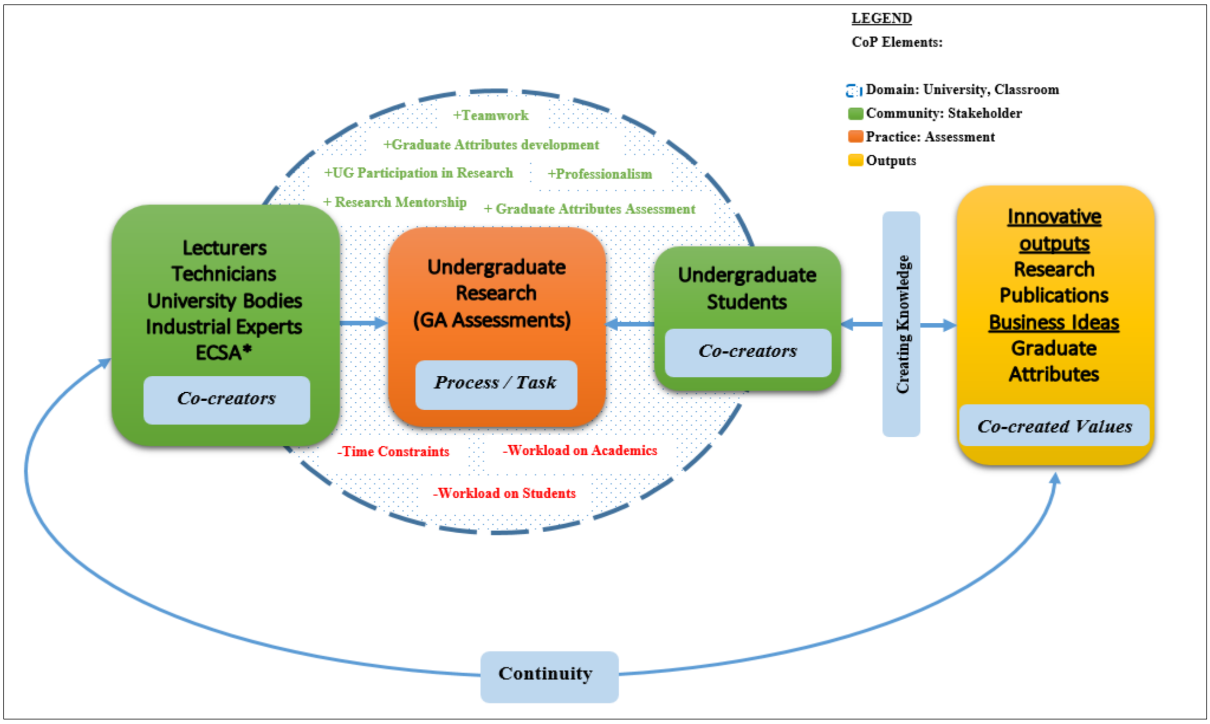

Figure 5: Undergraduate research enhanced model for graduate attributes development (Source: Authors' compilation)

Conclusion and Recommendations

This study assessed the impact of undergraduate research on engineering student GAs' development and assessment using a case study of civil engineering diploma students. The students were consulted to evaluate their views on the matter and how to improve the current methods if needed. From the students' responses, it was found that students' understanding and views do improve from Year 1 to Year 2 due to continuous exposure to research. It is the view of this study that introducing a research-focused module could help the students improve their skills, as suggested by their views in section 0 above. Additionally, the results of the study show that undergraduate research does influence the plans of students to enrol in postgraduate education, and at diploma level it has a significant influence on students' opinion of undergraduate research as a tool to assess engineering GAs.

This study has proposed a model for assessing and developing GAs among engineering students. This model illustrates the domain, where lecturers, technicians, industrial experts as external moderators, and ECSA interact with the undergraduate students. Methods of interaction will be expanded with the introduction of undergraduate research activities complementing the conventional assessments. Time and workload constraints can be leveraged with the concept of undergraduate research; in turn, various outcomes such as graduate attributes, publications, business ideas, and innovations that will benefit the universities and the students can be achieved.

In the light of how GAs are introduced and the general findings of this study, the following are recommended:

- Introducing a research methodology module from the early stages of the qualification will help the steady research growth on the students' side (Camara and Toure, 2010). This module's content needs to be aligned with the development of graduate attributes.
- Addition of a research component in the ECSA Qualification Unit Standards, including competency indicators for the research component. This will "compel" faculties to implement research and start a wide Undergraduate Research culture.
- Implementation of the conceptual framework proposed above to keep all stakeholders within the communities of the respective engineering departments within institutes continuously involved in the development and assessment of GAs.
- A monitoring regime be put in place to follow-up on the current research. This will assist in understanding the current state and continuous state of undergraduate research in diploma students.

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