Including hands-on experience in the teaching of research methods to graduate students

E Ogbeifun; JHC Pretorius.
University of Johannesburg, South Africa.
jhcpretorius@uj.ac.za

Introduction

Typical undergraduate engineering students demonstrate some level of research proficiency as they were involved in developing assignments, reporting on experiments, and writing technical and group project reports. However, when this group of students progresses to higher academic degrees, their outputs do not prove that they have substantial knowledge of the different types of research methods, research approaches and the ability to execute standard research. Therefore, relying on the assumption that these students have knowledge of research, providing generic information and lectures on research methods, without adequate hands-on sessions in the development of the different components of a research document usually makes supervision of graduate students difficult and time consuming.

The disconnect in the research proficiency of graduate engineering students can be summed up in the postulation of Håkansson (2013). He states that the majority of students embark on the research exercise before considering the research method and try to shape the work, after it has been carried out, to fit into any method. Some students may also adopt methods that do not suit their research and many students do not consider validity, reliability and replicability of their research effort or the consequences of the chosen research method on the research outcome (Håkansson, 2013). It is imperative, therefore, to guide the students to develop research strategies suitable for the different research methods to be able to execute a research exercise which produces correct, valid and reliable results. The panacea to this deficiency requires a two-pronged approach namely choosing a suitable research strategy and producing a coherent research report.

The emphasis at master's degree level is not on the need to develop a research protocol or the blue print of the step by step approach to be adopted in the execution of a typical research exercise. Nevertheless, master's degree students should be schooled in the act of relating the research strategy to the various components of the research exercise. This will enable them to know, from the onset that "the choice of research method must be driven by the research questions" (Borrego *et al*., 2009, p. 53). The research strategy should be the envelope containing the research method(s) and instruments used at the different stages of the research exercise (Håkansson, 2013). It is one thing to execute a credible research exercise, another crucial step is to produce a readable document. Proficiency in documentation is a skill to be learnt. The research document should provide a seamless narrative from the beginning to the end of the research document. The documentation of the process of data collection, analysis and synthesis of the result enables other researchers to replicate the process of the current research exercise (Borrego *et al*., 2009; Rogers & Goktas, 2010; Håkansson, 2013).

In order to improve the research proficiency of our engineering management master's degree students, two faculty members developed a three-step integrated strategy. The steps are: comprehensive comments on the output of each student in each component (chapter) of the dissertation; effective communication with each student, or group through email, telephone, other media (especially skype and WhatsApp) and face to face interactions; assisting students with relevant literature, educating them on how to search for suitable academic materials and how to extract useful information from literature. This paper reports on the progress being made on the implementation of this strategy by comparing the research

proficiencies of two groups of masters' degree students before and during the implementation of the strategy.

Literature review

A literature review provides the platform for current researchers to benefit from the efforts of previous research, in terms of models and methodologies to support new endeavours. The literature reviewed here provides general information on how substantial knowledge in research methods and strategies enhances proficiency in research.

a. Research methods

The majority of research by undergraduate and master's degree students in engineering centres around experiments and design, with few adopting the general principles of quantitative, qualitative or mixed methods approaches. Borrego *et al*. (2009, p. 53) observed that "given the wide variety of issues still to be explored within engineering education, we expect that quantitative, qualitative, and mixed approaches will be essential in the future. We encourage readers to further investigate alternative research methods". However, the choice of research method(s) should be driven by the research aim, objectives and the research question(s) (Borrego *et al*., 2009; Håkansson, 2013; Yin, 2014). In the research of Håkansson (2013), the section on 'portal of research methods and methodologies' provides a broad classification of the different research approaches, which can be used for classic quantitative or qualitative research, and others that could be employed on either side of the divide. The author suggests that a detailed research framework should be developed before embarking on any research exercise. The demand for a research framework is not a strict requirement at undergraduate and master's degree level, as much as it is expected at doctoral levels of study. A typical research framework suggests that the researcher should understand the basic philosophy and assumptions behind any research method.

Beside the exclusive quantitative and qualitative research methods, the mixed method, commonly referred to as "the third methodological movement" (Borrego *et al*., 2009, p. 57), is gaining prominence in general research as well as in engineering studies (Abowitz and Toole, 2009; Maxwell, 2016). Heeding the appeal of Borrego *et al*. (2009), that researchers should explore alternative research methods, the Delphi technique is assuming centre stage in engineering and the built environment research (Hallowell & Gambatese, 2010; Musonda & Pretorius, 2015; Alaloul *et al*., 2015). The Delphi technique is a hybrid research method that combines the qualitative and quantitative methodologies in one research exercise (Sekayi & Kennedy, 2017). The method can be used as a stand-alone tool or in combination with other tools. The strength or reliability of the technique centres on the quality of the participants, known as experts or panel of knowledgeable persons in the research area (Day & Bobeva, 2005). The participants are 'purposively' selected, not limited by geographical location and they can be few in number or as many as possible (Hasson & Keeney, 2011). The process goes through the repetitive cycles of the data collection, which may lead to high attrition rate (Day & Bobeva, 2005; Alaloul *et al*., 2015). It is imperative, therefore, to recruit a high number of participants at the beginning of the exercise in order to manage the negative effects of possible attrition (Donohoe & Needham, 2009). The factors influencing the reliability of the Delphi process includes ensuring the anonymity of participants' contributions and that the results are refined in every cycle of data collection. *Intrinsically, unless the graduate engineering student is guided in the art and science of research method, they will remain deficient in the organisation of the research exercise, documentation and its coherent presentation* (Håkansson, 2013).

As at 2009, the University of Puerto Rico-Mayagüez Campus (UPRM) offers 41 master's programmes in four colleges of the university, including 8 in engineering (Ayala-Gonzalez, et al., 2019). The master's programs of the institution were faced with the twin problems of decline in enrollment and proficiency in research (Quarterman, 2008; Ayala-Gonzalez, et al., 2019). Initial search for the factors responsible for the decline in research proficiency

identified a need for assistance with technical writing, communication skills, search strategies, research integrity, data management, research organization, and conducive space where teaching and research services coincided. In 2016, the Office of Graduate Studies (OGS) established the Graduate Research and Innovation Center (GRIC). The services rendered in the GRIC provides personalized set of services, aligned to the research lifecycle, such as scholarly communication, technical writing for graduate engineering students, library resources, and research data management (Crede and Borrego, 2012; Ayala-Gonzalez, et al., 2019). Since communication skills in English are fundamental in graduate research, especially for English as Second Language students (Macchiavelli, et al., 2014), the GRIC has also integrated peer-to-peer support, with a team of Graduate Writing Facilitators (GWF) (Ayala-Gonzalez, et al., 2019). Similar to what Beres and Woloshyn, (2017) did for graduate Chinese students, studying for education degree in Canada, by integrating formal learning in research method with small group sessions (Crede and Borrego, 2012). The GWF's are a team of three graduate students with diverse multidisciplinary backgrounds (Engineering, Science, and English), trained to offer academic services in oral and written communication in English to meet the needs of all our graduate programmes. Thus, improving the skills of the students in English grammar and style, tone and audience, visual design, transition and clarity, and oral presentations in general, as well as draft outlines for papers, polishing journal articles and thesis chapters. GWF service satisfaction surveys show that 54% of participating students belong to Engineering graduate programs (Ayala-Gonzalez, et al., 2019, p. 10).

b. Proficiency in research exercise

Research proficiency ought to progress continuously from undergraduate level up the ladder to doctorate studies, extending to professional practice or academic development. The level of proficiency should increase in depth, content and flow as the researcher progresses from one level to another. This progress requires the combination of hands-on exercises, consistent mentoring and the personal development of the researcher. There is a standard curriculum in the study of research methods on the undergraduate and graduate levels, which provides broad information on the use of the various research tools. Unfortunately, in the majority of situations, the classroom information on research methods is not complemented with adequate hands-on exercises, leaving the students ill prepared to conduct in-depth and independent research as is required at postgraduate level (Rogers & Goktas, 2010). In the detailed research of Rogers and Goktas, who sought to explore the proficiency of graduate engineering students in research, the authors focused their attention on three areas, namely "academic preparation to perform research, organisation in performing research and research progress" (2010, p. 264). The work of the duo corroborates earlier research efforts on the level of preparedness of graduate engineering students for research, observing that course work teaching in research methods, does not prepare engineering students sufficiently for the actual conduct of research (Walker *et al*., 2008). In addition, students who majored in civil engineering in their undergraduate studies and students whose native language is not English were discovered to be less academically prepared for the research work during their postgraduate studies. Chemical and environmental engineering students showed a marginally better level of preparedness (Rogers & Goktas, 2010). It is understandable why early career engineers may not be proficient in the management of research methods. This is because the majority of research conducted at this level is either experimental or design in nature and does not adopt the general framework of quantitative or qualitative research, which usually requires the use of extant knowledge of other subjects. Rogers and Goktas (2010) discovered that the deficiency in statistics exposure was a major factor in the lack of preparedness of graduate students for their research work as statistics is central to quantitative research methodology (Albers, 2017). The three other factors in which students were discovered to be poorly skilled were "communicating in writing, critically analyzing information and arguments, and conducting experiments" (Rogers & Goktas, 2010, p. 270). The writing skill of the students is critical in producing a successful and readable research document. It facilitates the coordination of all

relevant information, placing the narratives in systematic order to ensure a continuous flow of information which makes sense to the reader (Rogers & Goktas, 2010). Similar to the skills required in conducting and reporting experiments and design exercises in engineering, students require skills in the collection, analysis and reporting of data while using other research tools (Albers, 2017). The majority of master's degree students experience challenges in compiling the literature review, choosing a research method, completing data collection and analysis and presenting the discussion on findings of their research work.

Generally, the lack of an appropriate skill set in the development and use of a research strategy negatively affects the research preparedness of engineering graduate students in the conduct of the research component of their studies. This lack of preparedness is obvious in the organisation and performing of the research, making appropriate progress and documentation of the research exercise. In order to address the areas of concern, Rogers and Goktas (2010, p. 271), offered three solutions, summarised as follows:

a. Review curricular and extra-curricular activities with the aim of improving the knowledge of students in statistics, written communication and others.
b. Faculty members should provide a concerted effort through mentoring to improve the skills of time management and the general organisation of the research exercise.
c. Provide special attention to students with deficient backgrounds (in the authors' scenario, students with civil engineering and non-English language speaking backgrounds).

Similarly, Asplund and Grimheden (2019) suggested a re-orientation in the research training for master's degree students in engineering from 'teaching-centred to student-centred, and from research-related subject content to research-related processes. These suggestions require contextual application in order to improve on the research proficiency of graduate engineering students in any particular institution. This research adapted a synthesis of these two suggestions.

Research method

The comparative method of qualitative research (Yin, 2014) was adopted in the study of the research proficiency of some master's degree students. The objective of the study was to compare the impact of the current intervention on the improvement of the research proficiency of the graduate students, and by extension, the rate of completion of their master's degree studies. As it is in tandem with engineering practice, new proposals are usually tested in a pilot scheme before being implemented or being adopted for inclusion in the modification of existing operations (Frishammar *et al*., 2014). Therefore, this pilot study entails a comparison of the research proficiency of two groups of master's degree students. The population for this research, are the eight students in Group 1 and four students in Group 2, allocated to the two faculty members for joint supervision.

The data collection tool was a semi-structured, open-ended questionnaire complemented with selected interviews (McIntosh & Morse, 2015). The principle of content analysis was used to analyse the qualitative data based on responses from the students (Stemler, 2015; Vaismoradi *et al*., 2016). The synthesis of their responses helped in identifying the root causes and the factors responsible for the low research proficiency of the students in the first group. Other questions in the survey were aimed at evaluating the impact of the introduced strategies on the improvements on the research proficiency of the two groups. The findings reveal that the intervention has resulted in a remarkable improvement on the research proficiency of the students. This is seen in the quality of communication, rate of response and the number of times they develop the different chapters of the dissertation component. Details of the procedure, analysis and results are provided in the findings and discussion section.

Findings and discussion

This section provides information on the two groups of students used for this research. It demonstrates how practical interventions have facilitated improvements in the research preparedness and proficiency of graduate engineering students, comparable to the outcome of the research efforts of Rogers and Goktas (2010).

a. Background to the study

The two groups of students, used for this research, completed the course work component of the master's degree in 2017 and 2018 respectively, before commencing the research component of their studies. The students in both groups did not have any formal course work training on research methods. Neither did they attend any of the research orientation classes organised by the School before and during the execution of their research exercise. Due to the difficulties experienced in supervising the Group 1 students, the supervisors adopted the three-step integrated strategy in January 2019.

Eight and four students were allocated to the two faculty members for supervision, in the 2018 and 2019 academic sessions. Each student was expected to produce an acceptable research proposal before commencing on the research exercise proper. The dissertation (50% weight of a full master's) document, at the end of the research, should typically be a six-chapter document. In the case of the Group 1 students, some of the students went straight ahead and produced a document containing the first four chapters of the dissertation. These documents were basically in the form of lecture notes, copied from different source materials. It took a long while to educate this group of students on how to develop one chapter of the dissertation at a time. However, based on the observed lapses and the struggle to guide the students in the first group, the supervisors adopted the three-step integrated strategy. The strategy included detailed comments on the research output of each student on each chapter of the dissertation document; effective communication, which included the use of emails, telephone, other media (especially skype and WhatsApp) and face to face interactions. The third component involved assisting the students with relevant research materials, guiding them on how to source credible academic materials and how to extract useful information from literature. These steps have been tested since January 2019 and the results are encouraging. Consequently, four and two students from Groups 1 and 2, respectively have made remarkable improvements in their research efforts and documentation.

b. Research preparedness and proficiency

The research preparedness and proficiency of the two groups of students can be seen in the organisation of the research exercise, quality of communication and number of times they developed the different components of the dissertation document, as shown in Table 1. The table reflects the students' response to one of the critical questions in the survey: *How many times have you written the following components of your dissertation before your supervisor was satisfied?*

Table 1: Test of research preparedness and proficiency

		Research Component for master's degree dissertation						
	Year completed course work	Proposal	Chapter one	Chapter two	Chapter three	Chapter four	Chapter five	Chapter six
Group 1								
1	2017	4	3	3	4	11	3	
2	2017	3	2	3	4	7	3	
3	2017	3	3	4				

4	2017	3	3	3	4	5		
5	2017	3						
6	2017	2 (and not complete)						
7	2018							
8	2017							
Group 2								
1	2018	2	2	3				
2	2018	4	2	2				
3	2018	3						
4	2018							

At the end of 2018, Group 1 students were only able to progress up to Chapter 2 of the dissertation document. *This is because, it takes between four to six weeks for the student to develop and turn in a chapter document, as well as another strenuous two weeks before the supervisor can make sense out of the document.* The reasons volunteered by the students are: "They lacked understanding of what is required in each chapter and their inability to follow the supervisors' instruction". Consequently, since the introduction of the integrated strategy in January 2019, the students in the two groups have made significant progress. This is in consonance with the improvements observed by Rogers and Goktas (2010) and Asplund and Grimheden (2019), in their research. Comparatively, as at July 2019, Group 2 students have achieved what the Group 1 students had achieved in one year. Although the students still had multiple repeats, there is evidence that they are learning from their failures (Simpson *et al*., 2018).

The areas of major concern to students in Group 1 are Chapters 3-5. The first student in the group used the quantitative research method, collected useful data and produced volumes of tables and graphs as analysis, but was unable to relate the findings to the research questions. According to Albers, (2017, p. 215), "The goal of data analysis is to reveal the underlying patterns, trends, and relationships of a study's contextual situation". It took several attempts, employing multiple steps in the strategy, to extract meaning out of the data and the student is progressing to Chapter 6. The second student is using the mixed method. He has collected rich data but had constraints in extracting meaning from the analysis of the data. This problem is being resolved through the implementation of the strategy. Students three and four are using the qualitative research approach. They collected qualitative data but reported the results as quantitative data, which is a clear demonstration of research deficiencies (Håkansson, 2013).

Through the systematic adoption and implementation of the intervention strategies, the students in the two groups are making progress. After the successful completion of literature review, the first two students in Group 2 are at the level of data collection. *The rate at which they turn in the document for each chapter is faster than their counterpart in group 1 9between two to three weeks and takes one week for supervisors' response).* They have been schooled in the art of data collection, analysis and relating research strategy to the various components of the research exercise. The first student is using the Delphi technique – a hybrid method which integrates qualitative and quantitative research methods in one exercise (Hasson & Keeney, 2011; Sekayi & Kennedy, 2017). He will validate the results with a focus group session (Ogbeifun *et al*., 2016). The second student is using the multiple sites case study method of qualitative research (Yin, 2014) and hopes to use the principle of content analysis of qualitative data (Hsieh & Shannon, 2005) and triangulation to validate the data (Turner *et al*., 2015). Armed with this knowledge, it is hoped that the students in Group 2 will be able to complete the challenging Chapters 3-5 with relative ease and in better time than their counterparts in Group 1.

Conclusion and recommendation

The enthusiasm displayed by graduate engineering students during the course work drops significantly when they commence the research component of the study. The factors responsible for this low morale can be traced to the interrelated factors of the deficiency in research knowledge, development of suitable research strategy, relating research method(s), data collection and analysis to the research aim, objectives and the research question. Other factors include the lack of organisation in the conduct of the research and poor documentation skills. These factors lead to frustration, high attrition, an increased burden on supervisors and a reduction in the number of graduate students completing their studies. Adequate schooling in the development and use of a suitable research strategy has the potential of reducing the incidence of frustration, the high attrition rate of graduate students, as well as the burden of supervision. These deficiencies can be ameliorated through the inclusion of the concept of hands-on sessions in the teaching of research methods and complemented by contextualised mentoring systems.

However, due to the present absence of formal training for graduate engineering students in research methods and hands-on sessions, the supervisors in this research adopted the three-step integrated strategy in order to assist the students to overcome their deficiencies. The progress made by the students, notably, Group 2, has proven the strategy to be a suitable approach to improving the research proficiency of graduate engineering students and facilitating timely graduation. If the students in the two groups continue at the current pace, it is possible that they will be able to participate in the faculty's graduation event slated for April 2020.

This research has demonstrated improvement in the research proficiency of graduate engineering students where there was no prior evidence of training in research methods. The improvement was achieved through the adoption of practical strategies. This research recommends that further studies be done on the research proficiency of graduate engineering students where there is evidence of training in research methods and hands-on sessions, in order to validate the need for a curriculum or pedagogy review.

References

Abowitz D A and Toole M T, (2009), Mixed method research fundamental issues of design, validity, and reliability in construction research, *Journal of Construction Engineering and Management*, 136(1), 108-116.

Alaloul, W.S., Liew, M.S., Wan, Z. and Noor, A. (2015), Delphi technique procedures: A new perspective in construction management research, *Applied Mechanics & Materials*, 802, 661–667.

Albers, M. (2017), Quantitative data analysis—in the graduate curriculum, *Journal of Technical Writing and communication*, 47(2), 215–233.

Asplund, F. and Grimheden, M.E. (2019), Reinforcing learning in an engineering master's degree program: The relevance of research training, *International Journal of Engineering Education,* 35(2), 598–616.

Ayala-Gonzalez H T, Pomales-Garcia C D, and Alvarez J E (2019), Design, impact and best practices for a graduate research and innovation center, Proceedings of the 126th annual conference and exposition, *American Society for Engineering Education*, Tampa, Florida, June 15-19, 2019, Paper ID #25868, available online at: https://peer.asee.org/?q=Design%2C+impact+and+best+practices+for+a+graduate+research+and+innovation+center&commit=Search Accesses October 10, 2019

Beres J L and Woloshyn V E (2017), Instructional insights gained from teaching a research methods course to Chinese international graduate students studying in Canada, *Journal of International Students* vol. 7(3), 728-743.

Borrego, M., Douglass, E. and Amelink, C.T. (2009), Quantitative, qualitative, and mixed research methods in engineering education, *Journal of Engineering Education,* 98(1), 53–66.

Crede E and Borrego M (2012), Learning in graduate engineering research groups of various Sizes, *Journal of Engineering Education*, vol. 101(3), 565-589.

Day, J. and Bobeva, M. (2005), A generic toolkit for the successful management of Delphi studies, *The Electronic Journal of Business Research Methodology*, 3(2), 103–116.

Donohoe, H.M. and Needham, R.D. (2009), Moving best practice forward: Delphi characteristics, advantages, potential problems, and solutions, *International Journal of Tourism Research*, 11(5), 415–437.

Frishammar, J., Soderholm, P., Backstrom, K., Hellsmark, H. and Yilnenpaa, H. (2014), The role of pilot and demonstration plants in technological development: Synthesis and directions for future research, *Technology Analysis & Strategic Management*, 27(1), 1–18.

Håkansson, A. (2013), Portal of research methods and methodologies for research projects and degree projects. In: Hamid R, Bahrami A Z, Clincy V A, Deligiannidis L and Jandieri G (ed.), *Proceedings of the International Conference on Frontiers in Education: Computer Science and Computer Engineering FECS'13* (pp. 67-73). Las Vegas USA: CSREA Press U.S.A.

Hallowell, M.R. and Gambatese, J.A. (2010), Qualitative research: Application of the Delphi method to CEM research, *Journal of Construction Engineering and Management*, 136(1), 1–9.

Hasson, F. and Keeney, S. (2011), Enhancing rigour in the Delphi technique research, *Technological Forecasting & Social Change*, 78(9), 1695–1704.

Hsieh, H.F. and Shannon, S.E. (2005), Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9), 1277–1288.

Macchiavelli R. E., Alvarez J.E. and Juan Garcia E.J., Transformational Initiative for Graduate Education and Research, Title V, Part B *Promoting Postbaccalaureate Opportunities For Hispanic Americans Program* (PPOHA), 2014. Available at: https://libguides.uprm.edu/tiger/uprm , accessed October, 10, 2019.

Maxwell J A (2016), Expanding the history and range of mixed methods research, *Journal of Mixed Methods Research*, 10(1), 12-27

McIntosh, M.J. and Morse, J.M. (2015), Situating and constructing diversity in semi-structured interviews, *Global Qualitative Nursing Research*, 2, 1–12.

Musonda, I. and Pretorius, J.H.C. (2015), Effectiveness of economic incentives on clients' participation in health and safety programmes, *Journal of the South African Institution of Civil Engineering*, Vol. 157, Retrieved on November 2, 2016 from: http://www.scielo.org.za/scielo.php?pid=S1021-20192015000200001&script=sci_arttext.

Ogbeifun, E., Mbohwa, C. and Pretorius, J.H.C. (2016), Complementing a Delphi exercise with a focus group session*, Proceedings of the 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 4-7 Dec. 2016, Bali, Indonesia, 1269–1273, available online at**:** http://0-ieeexplore.ieee.org.ujlink.uj.ac.za/stamp/stamp.jsp?tp=&arnumber=7798082.

Quarterman J (2008), An assessment of barriers and strategies for recruitment and retention of a diverse graduate student population, *College Student Journal*, vol. 42(4), 947-967.

Rogers, S.W. and Goktas, R.K. (2010), Exploring engineering graduate student research proficiency with student surveys, *Journal of Engineering Education,* 99(3), 263–278.

Sekayi, D. and Kennedy, A. (2017), Qualitative Delphi method: A four round process with a worked example, *The Qualitative Report*, 22(10), 2755–2763.

Simpson, E., Bradley, D. and O'Keeffe, J. (2018), Failure is an option: An innovative engineering curriculum, *International Journal of Building Pathology and Adaptation*, 36(3), 268–282.

Stemler, S.E. (2015), Emerging trend in content analysis. In: Scott, R. and Kosslyn, S. (ed.), *Emerging Trends in the Social and Behavioral Sciences*, 1-14, John Wiley & Sons.

Tuner, S.F., Cardinal, L.B. and Burton, R.M., (2015), Research design for mixed methods: A triangulation-based framework and roadmap. *Organizational Research Methods,* November 25, 1–28, Retrieved on September 12, 2017 from: http://journals.sagepub.com/doi/abs/10.1177/1094428115610808.

Vaismoradi, M., Jones, J., Turunen, H. and Snelgrove, S. (2016), Theme development in qualitative content analysis and thematic analysis, *Journal of Nursing Education and Practice*, 6(5), 100–110.

Walker, G.E., Golde, C.M., Jones, L., Bueschel, A.C. and Hutchings, P. (2008), *The formation of scholars: Rethinking doctoral education for the twenty-first century,* San Francisco, CA: Jossey-Bass.

Yin, R.K. (2014), *Case study research, design and methods,* (5th ed.), Singapore: SAGE.

Copyright statement