# Contrasting three different academic assessments of a compulsory capstone module in power engineering indicates reliability!

**A.J. Swart and P.E. Hertzog**

*Dept. of Electrical, Electronic and Computer Engineering, Central University of Technology, Private Bag X20539, Bloemfontein, South Africa, 9300. Email: drjamesswart@gmail.com*

**Abstract:** Industrial Projects IV is a compulsory capstone module for students enrolled for the postgraduate Baccalaureus Technologiae (BTech) in Electrical Engineering (Power) in South Africa. Many graduates from the National Diploma course often struggle to pass this module at their first attempt. This may be due to a number of challenges, such as; struggling to integrate theory with practice; perceiving their postgraduate studies to be overwhelming; feeling anxious as a result of uncertainty about what is expected of them; not knowing how they will be assessed; and finally experiencing a lack of support and understanding from their mentors. The purpose of this paper is to highlight the course structure of a compulsory capstone module offered at a university of technology which has helped students to overcome some of these challenges. The paper further contrasts the assessment results of three different academics that were tasked with mentoring these power engineering students and evaluating their various submissions. Results show that the use of a variety of pedagogies enables postgraduate power engineering students to successfully attain academic success, while predefined rubrics are essential in achieving reliability and validity of assessments among different academics.

**Keywords:** Industrial Projects IV, capstone, UoT, theory, practice

## 1. INTRODUCTION

"In order to arrive at knowledge of the motions of birds in the air, it is first necessary to acquire knowledge of the winds, which we will prove by the motions of water in itself, and this knowledge will be a step enabling us to arrive at the knowledge of beings that fly between the air and the wind" [1]. These words, by Leonardo Da Vinci, well illustrate that man needed to gain knowledge of birds in air, knowledge of winds and knowledge of water motions to *enable* man to successfully fly! Conversely, students need to acquire knowledge of specific graduate attributes, which, if used effectively, can become the *enabler* in helping them to successfully achieve academic success. This is especially true with regard to capstone modules.

The purpose of a capstone module is to provide students with the opportunity of earning credits by integrating and applying knowledge and skills acquired from other modules so as to extract the best possible benefit from the programme in a particular career [2]. The integration of knowledge and skills in an electrical engineering capstone module often involves the design and development of an engineering project [3]. Large research projects within capstone modules have also been used for postgraduate Master's degrees [4] while many of these modules lend themselves readily to problem-based learning [5] where a number of graduate attributes may be assessed. Ten graduate attributes have been adopted by the Central University of Technology (CUT) and must collectively feature within a given qualification or curriculum [6]. These include sustainable development, problem solving, entrepreneurship, community engagement, numeracy, technological literacy, teamwork, communication, leadership and technical competence. Many of these graduate attributes exist in capstone modules, including the module Industrial Projects IV (IP4).

However, the assessment procedures for capstone modules pose challenges and need careful structuring [7] while the ever growing number of students registering for these modules provide logistical challenges. The purpose of this paper is twofold. Firstly, it aims to present the course structure for a compulsory capstone module offered to power engineering students at a university of technology, termed IP4. Secondly, it aims to contrast the assessment results of three different academics that were tasked with mentoring some 85 power engineering students and assessing their various submissions.

The importance of predefined graduate attributes is firstly established. The power engineering module (IP4) is then introduced and contextualized. The research methodology follows with the results which are presented in a series of graphs and tables conveying quantitative data.

## 2. GRADUATE ATTRIBUTES

The fundamental purpose of engineering education is to build a knowledge base and attributes to enable the graduate to continue learning and to proceed to formative development that will develop the competencies required for independent practice [8]. This highlights the need for academics to regularly review their course material and assessments to ascertain if they are assessing the right graduate attributes. These attributes must currently be required by Industry so that the graduate may successfully engage in independent practice. Graduate attributes form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practice at the appropriate level (IEA, 2013). The sum of these individually assessable outcomes must exist across an entire curriculum, and must not be confined to a singular module. These graduate attributes are exemplars of the attributes expected of graduated from an accredited programme (IEA, 2013). An accredited engineering programme often incorporates a capstone module, where students are required to draw on their knowledge and skills acquired in other modules to complete the desired learning outcomes. The 12 graduate attributes stipulated by the International Engineering Alliance are intended to assist signatories and provisional members to develop outcomes-based accreditation criteria for use by their respective jurisdictions (IEA, 2013). These 12 attributes may be linked to the 10 attributes adopted by CUT (see Table 1) which need to be demonstrated by all students.

Engineering knowledge refers to the ability of students to apply mathematics, science, and engineering fundamentals to engineering problems and is equated to the numerate attribute of CUT (see Table 2 for a definition). Problem analysis not only refers to the ability of the student to analyse complex engineering problems but also the ability to identify relevant literature to reach a viable solution (equated to the innovation and problem solving attribute of CUT). Engineering students must furthermore be able to design solutions for broadly defined engineering problems that often require the use of the right technical equipment (similar to the technical and conceptual competence attribute of CUT). The forth attribute indicates that students must be able to conduct investigations into complex problems, using relevant research methods and experiments to provide valid conclusions (also linked to innovation and problem solving using the iUSE model). Students must further be able to create, select and apply modern engineering and information technology tools with an understanding of their limitations. This is equated to technological literacy at CUT, where students need to use computer hardware and software in many of their practical assignments.

The Engineer and Society refers to knowledge of the societal, health, safety, legal and cultural issues which may be equated to the CUT attribute of community engagement. Engineering students must understand the impact of engineering solutions on the environment and must have the knowledge needed for sustainable development. They must commit to and understand professional ethics and responsibilities which may be linked to the citizenship and global leadership attribute of CUT. Students must furthermore be able to function effectively as individuals or as members of a team. Communication, in the engineering context, refers to the ability of the student to effectively communicate with society, to give clear instructions and to compile effective reports.

Project management and finance indicates that students must demonstrate knowledge and understanding of engineering management principles, being able to manage projects in multidisciplinary environments (this is similar to the citizenship and global leadership attribute of CUT). The last attribute refers to the student's ability to engage in independent lifelong learning, which is a key requisite of entrepreneurship. Many, if not all, of these graduate attributes may be assessed in capstone modules, such as IP4.

Table 1: Linking the graduate attributes prescribed by the IEA and by CUT along with succinct definitions

| International Engineering Alliance | Central University of Technology | Definitions of the CUT graduate attributes |
|---|---|---|
| **Engineering Knowledge** | Numerate | Performing correct calculations and equation manipulations |
| **Problem Analysis** | Innovation and problem solving | Promoting the iUSE model as described by Swart and Toolo [9] |
| **Design / development of solutions** | Technical and conceptual competence | Operating specific equipment or apparatus effectively in a laboratory |
| **Investigation** | Innovation and problem solving | Promoting the iUSE model as described by Swart and Toolo [9] |
| **Modern Tool Usage** | Technologically literate | Efficiently using computer hardware and software to complete assignments |
| **The Engineer and Society** | Community engagement | Encouraging students to benefit their communities |
| **Environment and Sustainability** | Sustainable development | Incorporating aspects of sustainability into a module |
| **Ethics** | Citizenship and global leadership | Including aspects relating to citizenship, leadership or management in a module |
| **Individual and Team work** | Teamwork | Nurturing group work of two or more students in a module |
| **Communication** | Communication | Promoting good written and oral communication in a module |
| **Project Management and Finance** | Citizenship and global leadership Numerate | Including aspects relating to citizenship, leadership or management in a module |
| **Lifelong learning** | Entrepreneurship | Featuring aspects relating to entrepreneurship in a module |

## 3. COURSE STRUCTURE OF IP4

IP4 is a compulsory module in the Baccalaureus Technologiae: Engineering: Electrical qualification, more commonly referred to by students as the BTech in Power Engineering. The course structure (highlighting six different submission requirements) used at CUT for this module is shown in Table 2, which needs to be completed over a 1 year period (registration takes place in January with the final assessment in October). No formal electrical or electronic based project or operational circuit is required from these students who often work with power systems up to 132 kV. Their final summative report or dissertation is usually based on a real life case study which exists in Industry.

The structure and purpose of the project proposal along with the research methodology course and project plan is presented over the first 9 weeks. This usually comprises a singular 4 hour session per week arranged for a late afternoon / early evening in order to grant full time working students the opportunity to attend. Theory relating to the title, problem statement and proof of the problem is emphasized! The project proposal is assessed formatively, giving students the opportunity to rectify any deficiencies. This is important as the project proposal usually forms the core of the first chapter in the final summative report or dissertation.

Table 2: Course structure of IP4

| Requirement | Month | Weighting |
|---|---|---|
| Project proposal | April | 10% |
| Progress formative report | July | 10% |
| Article | August | 5% |
| Poster | August | 5% |
| Oral presentation | September | 10% |
| Final summative report | October | 60% |
| | **TOTAL** | 100% |

The formative progress report covers the first three chapters of the dissertation, along with the front matter (declaration, expression of thanks, abstract and table of contents), references (a minimum of 12 references are required of which at least 50% must be journal references). In-text references are emphasised as well as the importance of plagiarism. The first chapter basically comprises the updated project proposal, while Chapter 2 should cover relevant literature that supports the problem and the proposed solutions. Students are requested to include specific references to previous practical Industry examples where their proposed solutions to their problem have been used before. This lends credence to their proposed solution, establishing its validity in the student's research project. Reasons must be given with regard to WHY the solution was required, HOW it was implemented and WHAT the results were. Chapter 3 of the progress report should introduce at least three proposed solutions to the problem, presenting proposed electrical diagrams, possible installation sites, geographical topologies and the advantages and disadvantages of each solution.

The article requires students to compile a two page article based on the official IEEE template. This helps students to understand the importance of structuring a research publication as well as what important sections or topics need to be covered. Limiting the number of pages helps negate the so called "cut and paste" syndrome so often encountered with student reports or dissertations. Students cannot simply copy a huge amount of data from the Internet or from another study, but need to evaluate the information and select only that which is relevant, phrasing it in such a way that it makes sense to the reader. All figures and tables need to be edited by the student to include 3 specific highlighted sections / blocks which need to be explained in the text. This helps students to reason on the figures and tables, interpreting their significance in the context of their study.

An A3 poster is required where the student must provide at least 4 sketches or figures relating to the current geographical layout, proof of problem and results. Each figure must be briefly explained with two brief sentences below or above the figure. In addition, each figure must have three key aspects highlighted. This discourages students from simply cutting and pasting images from the Internet or software packages, with no substantial interpretation or explanation. A brief problem statement and conclusion section is required, while no references must be given on the poster. The inclusion of excessive amounts of text is discouraged.

The oral presentation requires students to complete a 14 slide PPT where their details, problem statement, proof of the problem, three possible solutions and results must be shown. Excessive amounts of text are discouraged, while the results must feature some type of simulation in order to make an informed decision about the preferred solution. All possible solutions must be visually presented, with as little text as possible. The conclusion must state the preferred solution and provide substantive reasons for this decision.

The final summative report comprises the largest weighting towards the student's final mark which is based on academic feedback given to the student with regard to the progress report (Chapter 1 – 3), article and presentation. The final dissertation must include chapter 4 (results section comparing the alternative solutions by means of simulation software and cost analysis) and chapter 5 (conclusion of the project substantiating the use of the preferred solution along with pertinent recommendations). 40% of the final dissertation is awarded to the structure of the portfolio, the front matter (declaration, expression of thanks, abstract and table of contents) and the back matter (references and annexures). 60% of the final dissertation is awarded to the actual content of the five chapters.

Table 3 correlates the 10 graduate attributes of CUT to the six requirements of the IP4 module. This capstone module, requiring knowledge from previous modules, features seven of the ten graduate attributes adopted by CUT, with the most dominant ones being problem solving, technological and technical literacy!

Table 3: Graduate attributes required in IP4

| Requirement | Problem solving | Community engagement | Technological literacy | Numeracy | Teamwork | Communication | Technical literacy |
|---|---|---|---|---|---|---|---|
| Project proposal | √ | √ | √ | √ | √ | √ | √ |
| Progress report | √ | | √ | √ | √ | √ | √ |
| Article | √ | | √ | | | | √ |
| Poster | √ | | √ | | | | √ |
| Oral presentation | √ | | √ | √ | √ | √ | √ |
| Final report | √ | | √ | √ | √ | √ | √ |

## 4. ASSESSMENT RUBRICS

Rubrics are tools for assessing learning outcomes and evaluating critical thinking skills and are currently of interest given a changed emphasis in education [10]. The learning outcomes were defined for each submission, where after the rubrics were designed. Assessment rubrics are written to guarantee proper understanding of the expectations among various assessors, resulting in fair assessments [11]. This leads to the transparency, reliability and validity of the final results. Rubrics can also be used to provide a mapping of learning outcomes and graduate attributes within minimum standards to allow students to evidence their skills beyond the assignment criteria [12]. This provides a scale from not the criterion NOT being present to the criterion being EXCELLENTLY mastered (see Table 4). This gives rise to an analytical rubric. Analytical rubrics are scored by assigning individual scores to each criterion which are added together to create a total score, while a holistic rubric takes all of the criterion into consideration to develop a composite score without assigning sub-scores [13].

An assessment rubric was developed for each of the six requirements and is included in the study guide which is electronically made available to all registered students at the start of the module. Students are thus well informed of how and where marks will be allocated for their different submissions. This lessens, to some degree, the anxiety that some students experience in compulsory capstone modules in not knowing how they will be assessed [14]. Space does not allow for the presentation of all six rubrics.

However, the fundamental structure of the rubrics is shown in Table 5. 15% is generally awarded to the layout of the submission, which assists students to understand the individual requirements for each submission. The introduction and explanation of figures and tables is awarded the largest weighting (35%), as this is usually equated to the content of the dissertation. Chapter 4 of many engineering dissertations primarily contains figures and tables showing the results of the project [15], and forms the basis for the conclusion chapter where the original problem is finally addressed with a suitable validated solution.

Table 4: Generic summarised rubric used by all three academics in assessing the six required submissions

| Requirement | Criterion not present (0) | Criterion NOT mastered (1-4) | Criterion PARTIALLY mastered (5-6) | Criterion SUFFICIENTLY mastered (6-7) | Criterion mastered BEYOND expectations (8-9) | Criterion EXCELLENTLY mastered (10) |
|---|---|---|---|---|---|---|
| Layout according to the given template with all student details | Usual average weighting of 15%<br><br>Consistency in font size, spacing, structure and term usage required | | | | | |
| Introduction includes general background, problem statement, proof of problem and time line | Usual average weighting of 20%<br><br>The proof of the problem must support the problem statement by means of a figure or table | | | | | |
| Figures and tables are introduced and explained in the text and are relevant to the work | Usual average weighting of 35%<br><br>A minimum of three figures / tables are required for each chapter with 3 relevant aspects highlighted by means of a block | | | | | |
| At least 12 correctly formatted references are given with 50% from journals | Usual average weighting of 15%<br><br>At least 1 correctly formatted in-text reference per page for Chapters 1 – 3 must be correlated to the full reference | | | | | |
| Annexures are provided and relevant to the work | Usual average weighting of 5%<br><br>At least 1 relevant annexure | | | | | |
| Grammar and language quality | Usual average weighting of 10%<br><br>Acceptable language and grammar usage required which can be checked by peers | | | | | |

## 5. RESEARCH METHODOLOGY

A case study using quantitative data is used. A case study intends to explore a bounded system in-depth [16]. A system could refer to a programme, event or activity (in this research it is the grades awarded to IP4 students for the various submission as outlined in Table 2), while the word bounded implies that the research is conducted within the boundaries of a specific place (in this research it is CUT). A singular case study was used by Lajoie et al. [17] to describe in detail an online international problem-based learning approach. Quantitative data is used to highlight the grades awarded by three different academics to a group of 85 power engineering students during 2014, which form the target population for this study. The three academics include an Associate Professor (A/P), a Senior Lecturer (S/L) and a Lecturer (L). All three academics have more than 20 years of academic experience. This quantitative data is given in the form of tables and figures, with a histogram contrasting the three academics assessment of the final summative dissertation. Students are required to achieve an overall grade of more than 50% to successfully complete this module. The assessment of all the power engineering students' submission for 2014 followed the same process as that outlined under the course structure in the previous section.

## 6. RESULTS

Table 5 shows the profile of the three academics that were tasked with mentoring and assessing the IP4 students during 2014. All three academics have 20 years or more academic experience, having lectured more than seven different modules over this time period. Professors and Associate Professors usually constitute the most highly qualified and experienced academics [18], and would be more productive in terms of publications [19]. This suggests that the AP would be more experienced in academic writing, having a well-grounded understanding of what research really entails and how an article or poster should be structured. This further suggests that the A/P would more critically assess the six required submissions than would the other two academics.

Table 5: Academic profile

| | A/P | S/L | L |
|---|---|---|---|
| Highest qualification | DTech | DTech | BTech |
| Year joined academia | 1995 | 1992 | 1993 |
| Number of modules lectured | 14 | 13 | 7 |
| Number of journal articles | 22 | 10 | 0 |
| Number of completed M's and D's | 3 | 9 | 0 |

Figure 1 through 3 highlights the distribution of final grades awarded to the IP4 students by the three academics. Figure 1 presents the grades awarded by the A/P, where the majority of students received between 50 and 60%. Figure 2 illustrates that the S/L awarded more grades between 60 and 70% than the A/P did. This trend is also observed for the L, but to a lesser degree.

Figure 4 presents some of the descriptive statistics of the final grades awarded by the three academics. The maximum grade awarded varies between 65% (for the S/L) and 69% (for the L). The mode (value that occurs most often), median (value with half the grades above and below it) and mean are very close together for both the L and S/L, suggesting a normal distribution which is symmetrical or bell-shaped. The A/P values are also relatively close together (52% for the mean and 55% for the mode. The Kurtosis values in Figure 5 suggest a platykurtic distribution (kurtosis less than 3) rather than a leptokurtic distribution (kurtosis more than 3).

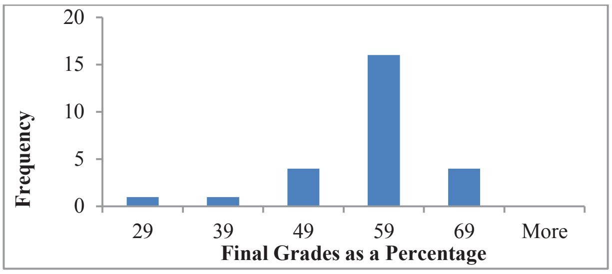


Figure 1: Histogram showing the distribution of final grades as a percentage awarded by the Associate Professor (A/P) – (n = 26 and throughput = 77%)

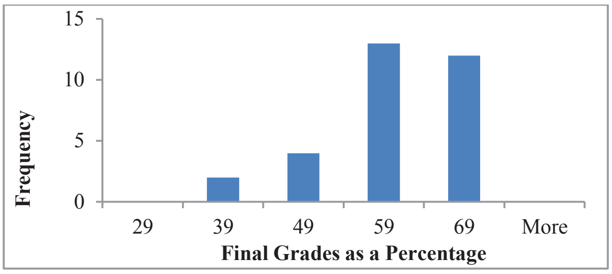


Figure 2: Histogram showing the distribution of final grades as a percentage awarded by the Senior Lecturer (S/L) – (n = 31 and throughput = 81%)

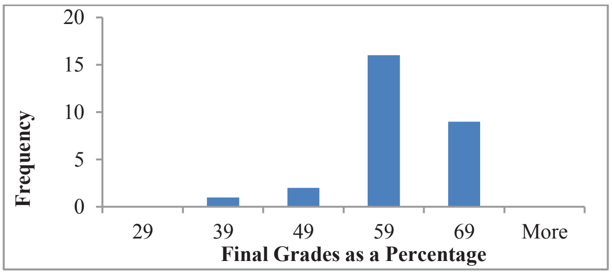


Figure 3: Histogram showing the distribution of final grades as a percentage awarded by the Lecturer (L) – (n = 28 and throughput = 89%)

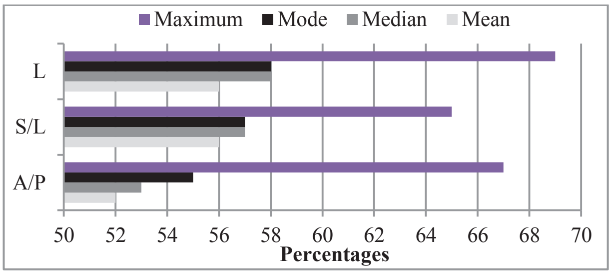


Figure 4: Descriptive statistics of the final grades awarded by the three academics

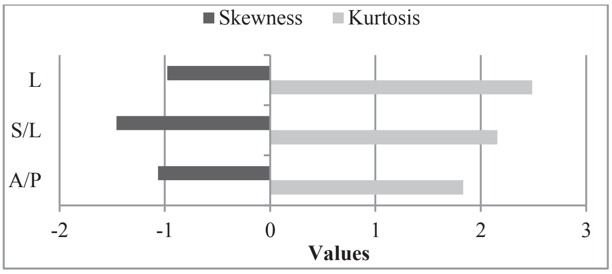


Figure 5: Skewness and Kurtosis values of the final grades awarded to IP4 students by the three academics

Figure 5 indicates a low degree of clustering of values. This suggests that all three academics strove to apply the rubrics to each individual student, not grading each submission in a nonchalant manner.

## 7. CONCLUSIONS

The purpose of this paper was to present the course structure for a compulsory capstone module offered to power engineering students at a university of technology and to contrast the assessment results of these students by three different academics. The A/P mentored 26 students, of which 77% successfully passed the module. The S/L mentored 31 students, of which 81% were successful. The L mentored 28 students, where 89% achieved a final grade of 50% or more. This may suggest that the A/P was a little more critical in the assessment, drawing on his previous experience in academic writing for publication. All three academics used the same predefined analytical rubrics to assess six different submissions, including a proposal, a progress report, an article, a poster, an oral presentation and a final report. The low negative Skewness results indicate that no extreme grades were awarded by any of the academics, while their maximum grade varied by only 4%. The Kurtosis values (lower than 3 indicating a flatter distribution) also bear testimony to this. These results tend to suggest that the rubrics were applied consistently by the three academics, resulting in the reliability and validity of the assessments in this compulsory capstone module.

## 8. REFERENCES


[1] Brainy Quote. (2015, 9 January 2015). *Homepage*. Available: http://www.brainyquote.com/quotes/

[2] A. Burger, "Research support for masters students," *Administratio Publica,* vol. 17, pp. 94 - 115, 2009.

[3] A. J. Swart*, et al.*, "Exploring the relationship between time management skills and the academic achievement of African engineering students - A case study," *EJEE, European Journal of Engineering Education,* vol. 35, pp. 79 - 89, 2010.

[4] I. Horrocks, "Developing a Capstone Research Module for Multiple Masters Qualifications at the Open University (UK): The Case of T847," in *Proceedings of the 13th European Conference on Research Methodology for Business and Management Studies: ECRM 2014*, 2014, p. 177.

[5] S. Kilcommins, Ed., *Capstone courses as a vehicle for integrative learning* (Integrative Learning: International research and practice. New York: Routledge, 2014, p.^pp. Pages.

[6] N. Luwes and A. J. Swart, "Student Perspectives of Practical Work done in a Laboratory – a Case Study from Logic Design III " presented at the ICEE 2015, Zagreb, Croatia, 2015.

[7] E. Farisani, "Impact of new policy developments in higher education on theological education," *Studia Historiae Ecclesiasticae,* vol. 36, pp. 287-303, 2010.

[8] International Engineering Alliance. (2014, 12 December 2014). *Homepage*. Available: http://www.ieagreements.org/GradProfiles.cfm

[9] A. J. Swart and L. E. Toolo, "Fundamental problem-solving skills are found across the board in education: Are our power engineering students on-board?," presented at the ICEE 2015, Zagreb, Croatia, 2015.

[10] A. Hebble and M. Richards, "Assessing student critical thinking skills for online quantitative courses," in *Fifth Annual General Business Conference*, 2013, p. 214.

[11] P. Desai*, et al.*, "A novel approach to carrying out mini project in Computer Science & Engineering," in *Engineering Education: Innovative Practices and Future Trends (AICERA), 2012 IEEE International Conference on*, 2012, pp. 1-4.

[12] S. McKenzie and G. Wood-Bradley, "Using rubrics in IT: Experiences of assessment and feedback at Deakin University," in *Teaching, Assessment and Learning (TALE), 2014 International Conference on*, 2014, pp. 474-479.

[13] K. D. McConnell, "Rubrics as catalysts for collaboration: a modest proposal," *European Journal of Higher Education,* vol. 3, pp. 74-88, 2013.

[14] B. Mavis, "Assessing Student Performance," in *An Introduction to Medical Teaching*, ed: Springer, 2014, pp. 209-241.

[15] M. Đ. Carić*, et al.*, "Construction and techniques of writing a scientific paper in natural and engineering sciences," *Zbornik Matice srpske za prirodne nauke,* pp. 119-128, 2013.

[16] J. Creswell and V. Plano Clark, *Understanding research: A consumer's guide*. Upper Saddle River, NJ: Pearson Education, Inc, 2010.

[17] S. P. Lajoie*, et al.*, "Using online digital tools and video to support international problem-based learning," *Interdisciplinary Journal of Problem-Based Learning,* vol. 8, p. 6, 2014.

[18] S. Badat, "Producing, transforming the social composition of, and retaining a new generation of academics: The Rhodes University programme of accelerated development," in *University Leaders Forum: Developing and retaining the next generation of academics, Accra, Ghana*, 2008.

[19] M. Bravidor, "What Determines Time Spent in Peer Reviews?–Evidence from The Accounting Review," *Evidence from The Accounting Review (November 30, 2013),* 2013.