Development of a competency-based work-integrated learning program to facilitate science, engineering and technology retention in South Africa as a developing country

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Presentations and arguments in this paper support the development of competencies in work-integrated learning, associated with engineering trainees. Competencies developed through this program are intended to facilitate the retention of science, engineering and technology within the workplace in South Africa, as a developing country. The unique program, as developed and conducted, presents a local paradigm shift in academic accreditation, which is based on the learning experiences recorded by the trainee in industry. The training standard in industry is thus established through a mutually exclusive agreement to focus on the trainee and the training in industry through the lens of academia as the qualification awarding entity. Systemic trainee confidence in the higher learning and retention aspects of knowledge is fostered through; learning, teamwork and co-operation and multidisciplinary initiatives to facilitate industrial responsibility and hence competency. The veracity of the program, in its approach and implications, is sharply contrasted against the current system operating in other engineering academic departments within the South African Universities of Technology movement. (Asia-Pacific Journal of Cooperative Education, 10(2), 65-74).

KEYWORDS: Work-integrated learning, competency, science, engineering, technology, universities of technology, South Africa.

Developing countries are experiencing a flight of technology (Khan, 2004) where individuals with transportable skills are leaving the workplace or their country. This tendency denudes the immediate competency base of industry and commerce, creating a latent technology drag, scenario, where vacancies are not filled or are filled by competently immature replacements. Abetted by political upheavals, such a tendency impacts on the national society and, if followed by a withdrawal of foreign investments, such a developing country can readily be termed a regressing country. Reestablishment from a regressing to a developing country calls for dedicated political will and the re-nurturing of competencies and economic growth. During such an overall scenario the national populace endures extreme hardships. One only has to reflect on the sovereign countries recently affected, such as Mozambique and lately Zimbabwe. South Africa is no exception in this trend and or parts of the above scenario. Democratization of South Africa from a repressive past to an emerging modern democracy has seen profound political re-adjustments, to gain the acceptance of the wider world community as an emerging democracy. Certain un-consolidated historic legacies from our past (Buzan, 1991; Fine & Rustombee, 2006; Thomson & Lamar, 1981; Turton, 2008) threaten the continued unification of South Africa. Our overall national transformation from our immediate political past as a segmented society to an Afro-centric inclusive democracy is still incomplete. As a developing country, subject to the flight of technology, we further have to appreciate and recognize the national ability to develop social ingenuity which can translate into technical ingenuity. The latter arising out of what is called social ingenuity being termed by (Homer-Dixon, 1995; Turton, 2008) as the capacity of a nation to generate incentives that create the institutional environment in which technical ingenuity could be generated.

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Allied to these factors is the national constitutionally enshrined expeditious redressing of imbalance of the past, relating to racial and gender equality. All facets of national society are currently impacted on by these necessary redresses and de-stigmatization. These national transformational changes have unfortunately resulted in unexpected side effects and pitfalls which fall outside this present discussion. The prevalent diminished level of graduate engineers and their competencies which are entering industry and their ability to support an existing and rapidly expanding societal infrastructure is problematic as elucidated by Turton and others (see, D'Almaine, Manhire & Atteh, 1997; Du Toit, Roodt, 2009; Turtin, 2008) and supported by the engineering press in related articles (Engineering Council of South Africa, 2009; Engineering News, 2009).

Being a realist as opposed to an alarmist, the author seeks to translate these national imperatives and resultant diminished capacities into the electrical power sector (McDonald, 2009; Munasinghe, 1989; Spalding-Fetcher, 2003) where one must appreciate the necessity of technical competence in this sector in both developed and developing countries. Continuity of electric supply, impacts on all strata of modern society in both essentialities and convenience. Whilst developed countries, nationally are indicative of near 100% connectivity and continuity of supply, developing countries reflect wide variations in both connectivity and continuity of supply (McDonald, 2009).

South Africa, prior to its modern democratization in 1994 and up to 2007, enjoyed a national near 100% continuity of supply, whilst rural electrification as a socioeconomic necessity, was rapidly expanded to yield an overall national electrification factor of 81.5% (Statistics South Africa) by 2007. During January 2008 South Africa experienced a predicted shortfall of its electrical power generation capacity with subsequent major power outages, enforced reduction in consumption, leading to a national annual growth rate reduction, conservatively estimated as from 5% to 2%.

Numerous large-scale heavy industries, notably the mining and manufacturing sectors were compromised and subsequently now operate with lower production outputs. This status quo will be maintained until newly developed and currently being built, power generation capacity is normalized (predicted from 2011 onwards). Predictably, during this development period, economic growth and rural electrification will be restricted. This unfortunate deficit is ameliorated by the current world-wide economic down-turn, which still sees the average grid connected South African consumer being provided with energy, however not at a near 100% continuity. Against this back-drop the South African universities of technology place their engineering students as work-integrated learning trainees in industry.

PROGRAMME-ISSUES

Engineers in South Africa are graduated at classical universities within a BSc(Engineering) program, comprising four years of academic training followed by a year of professional developmental in the industry. Another engineering graduation route is followed at universities of technology under a BTech (Engineering) program. The latter program require a period of two years academic study followed by one year of practical training called work-integrated learning, before graduating as a technician with a diploma in engineering. The graduated technician completes another year of academic studies to be graduated as a technologist within the BTech (Engineering) program.

Both qualifications are rated and assessed in terms of the South African Qualifications Authority, but require a further post graduation period of professional development within the industry to qualify for professional registration. The disparity existing between the programs and foci of engineering cooperative education associated with the respective engineering qualifications is evident further in the professional status awarded. The Engineering Council of South Africa accords the BSc(Engineering) as a PrEng whilst the BTech(Engineering) is accorded PrTech status (Engineering Council of South Africa).

This disparity of professional status is rooted in the academic training period within the notional hours mandated for academic accreditation at graduation. The BSc(Engineering) is considered as a four year qualification, whilst the BTech(Engineering) is rated as a three year qualification. The latter, however, comprises a one year period of work-integrated learning sandwiched between the two academic periods. The academic reporting of the learning experiences are classically recorded in a so called log-book without guidance as to the academic or reporting standards expected. This document can only be assessed in terms of outcomes against the South African Qualifications Authority level rating of 4. The latter rating is considered to fall in the secondary education band, and not in the tertiary education level (i.e., Level 5 and above) as per the mandated requirements (South African Qualifications Authority). This work-integrated learning as classically defined, managed and assessed within the universities of technology, incorporating a log-book, is thus at the heart of the problem in terms of ill-defined academic outcomes, and hence this non professionally recognized year of work-integrated learning.

PROBLEM INTERVENTION STRATEGY ADOPTED

The strategy adopted by the Department of Electrical Power Engineering at the Durban University of Technology in addressing the academic accreditation of the one year of work-integrated learning from the ill-defined log-book system to a portfolio was through a process of discussion and review. Consultations with our external peer institutes through a constituted Electrical Power Forum serving common education and cooperative education matters were inconclusive as the consensus ruled that the log-book system was functional and met the minimum requirements. Our proposed initiative was then discussed internally with our constituted academic-industrial liaison committee, comprising departmental academics and a representative panel of industrialists as classical service providers of cooperative education to our departmental learners. This forum recognized the advantages of our proposed enhanced system and urged the department to develop a portfolio system to replace the log-book system. The directives issued were for a system that met the following requirements:-

- Meet or exceed the national requirements of the South African Qualifications Authority;
- Be generic in style to accommodate the broader industry in terms of technology and workplace specific exposure;
- Facilitate in meeting expected workplace competencies, pertinent to those of applicable technologies, allied to, lifelong learning and personal development;
- Facilitate trainee developed reports that could be assessed against known standards;
- Provide individual accreditation of the trainee in his/her particular learning environment within the industry; and
- Provide relevant feedback mechanisms to all parties associated with the program.

Realities further dictated an overhaul of the application document to register the period of work-integrated learning to dovetail with the proposed portfolio system of reporting.

CHALLENGES EXPERIENCED

The major hurdle experienced was in qualifying and quantifying the terminology and precepts surrounding competencies and how these were to be specified, developed and assessed within a work-integrated learning program. Competency as defined and supported in current literature and as reflected amongst other by (Boyatzis, 1982; Spencer & Spencer, 1993) may be thought of as "an individual's underlying personal characteristics that facilitates superior performance in a given situation" (Coll, Zegwaard & Hodges, 2002; p. 36). Allied to this definition is the contextual relationship to the individual's attributes to achieve competency (Birkett, 1992). Capability is further viewed by Rudman (Rudman, 1995) "as a precursor to competency" (Coll et al., 2002; p. 36).

Considering the previous precepts and allied to statements from (Birkett, 1993), inferring that successful performance, whilst dependent upon a range of skills, would require both cognitive as well as behavioral skills. The author would argue that an holistic approach be taken, in that competency be further considered "as the required response to ensuring that a task is completed with due diligence with the task at hand and the expected outcome". Adaptations incorporating the diffusion of the definition of competence and its application per se, within the context of the academic-industrial situation of academic learners in the industry, must further support the National Qualifications Framework outcomes.

DEVELOPMENTAL ISSUES

The portfolio system development strategy evolved from mature academic reflection centered about competencies, their facilitation, development and assessment based on accepted principles of pedagogy and current good practice as supported by co-operative education literature. (Ashton & Sung, 2002; Coll & Eames, 2004; Moon, 1999; Eraut, Alderton, Cole & Senker, 1998; Fuller & Unwin, 2002; Kraak, Paterson, Visser & Tustin, 2000). The development of this program was further mirrored against current good practice at inception and whilst the program is in operation, with other similar technology applications within South Africa and other developing countries (Aleisa, 1995; Aleisa & Alabdulahfez, 2001; 2002; Coll, Pinyonatthagarn & Pramoolsook, 2003; De Lange, 2001;, 002; Reinhard, 2006; Groenewald, Bushney, Odendaal & Pieters, 2004)

Whilst focusing on the competencies to be developed in the engineering trainee, the academic partner (our department) had to apply due diligence in setting up a meaningful system in facilitating the academically-measurable competencies that could be developed in the industry. The academic competencies were established using the National Qualification Framework as contained in the South African Qualifications Framework documentation (South African Qualifications Authority, 2009). Work-integrated learning within the universities of technology comprises two six month or semester training periods. The first referred to as *Practical Training 1* is pegged at gaining national qualifications framework level 5 competencies. The second period called *Practical Training 2* is targeted in achieving national qualifications framework Level 6 competencies.

In terms of available literature (South African Qualifications Authority; Engineering Council South Africa) and the fact that range and academic outcome statements of the accepted academic program of outcomes-based education comprises mesmerizing cross-field outcomes, our academic department standardized the outcomes as those applicable to an engineering technician when graduating.

Logically and rather simplistically these may be thought to comprise:

- **National qualification framework Level 5**. At this level, the academic reporting structures requires the incorporation of past academic theories to support the learning experiences in the industry, which one may consider as *theory enhanced reporting*. The operative driver being "WHY?" In this reporting standard the learner will query the industrial learning experiences by providing and reflecting on prior-learned academic theories. Reports conducting this enquiry, assure that the academic experiences are supported and reinforced by practice experiences. At completion of training at this level the trainee in industry develops the confidence of hand skills allied to the profession and should be well versed in the underlying academic theories on which these practices are based; and
- **National qualification framework Level 6.** Academic skills at this level comprise the cumulative effect of the National Qualification Framework level 5 skills, transferred to real-world applications in terms of engineering problems and their solutions or to the elevated realms of technical problem synthesis and situation scenario sketching or simplistically referred to as "WHAT IF?".

The major challenge experienced was that all practical industrial training was leveled by South African Qualifications Framework as being national qualification framework level 4 or equivalent, to the secondary education exit level and thus in-appropriate for tertiary education. However, if one consider that practical training, per se, must start with the basic elements of doing physical work, through the process in skills accumulation, menial training progresses through confidence and when allied with theory enhanced reporting is translated into the national qualification framework level 5 standard.

Other challenges and interventions in meeting the required outcomes were in:

- Developing a meaningful documentary registration system to provide prior departmental approval for appropriate training to be conducted in the industry. The documentation had to be designed to foster broad-based appropriate training and hence ensure later industrial articulation without compromise to the integrity of the qualification. The intervention incorporated a document in the form of a memorandum of understanding, in generic format, with minimal prescription to facilitate both elective and industry motivated training entries. Appropriate technologies to be covered as well as the competencies to be developed are indicated and validated within this document by the industrial service provider that these would be developed at the conclusion of the training period;
- Developing a robust generic reporting system in which all industrial reports and on-site assessments could be compiled and presented to the academic department for final assessment in terms of the required National Qualification Framework level outcomes. A portfolio outline was designed to meet the requirements. This document comprises a training technology report outline in which guidance is given in the form of appropriate entry headings under which the required outcome standard could be developed. The report outline further contains a mentor assessment section against which each report is assessed on-site. The portfolio outline is concluded with a final on-site assessment report which is completed after the trainee provides a presentation to a panel of mentors closely associated with the individual's training. The latter comprising a valuable reflective insight into the on-site training that was conducted. Complete portfolios comprising the required reports are compiled by the learner and sent for academic evaluation and outcome against the established standards; and
- Facilitating veracity of the expected training to be conducted as approved in the memorandum of understanding. To this end even the simplistic system required academic visits to industry to monitor and discuss the trainee's progress. Our enhanced system validates the training of the trainee in the industry through the use of industrial visit reports, which queries both the training and the trainee's advancements within the program.

UNIQUE FEATURES

The following unique features as presented in this paper focus on the mechanisms to facilitate the trainee's insight in questioning the prior-learnt theory in terms of the technology presented in the industry. The following aspects are indicative of our enhanced or competency based work-integrated system:

- The program establishes a prior approved registration system in which the competencies to be developed by the trainee in the industry are indicated and agreed upon by all parties in the co-operative tri-party association;
- The work-integrated learning registered trainee, conducts the specified training in industry and completes an academic portfolio in which reports are completed in terms of competencies developed;
- Training reports are academically assessed against known academic standards to yield equitable outcomes, commensurate with a one year project in industry. This we as a department believe negates the academic professional registration pitfall previously discussed;
- The program facilitates a permanent cognitive mindset in the trainee which should translate into a knowledgeable engineer, adept in the intricacies of engineering problem solutions. This mindset is arguable perceptive to ingenuity and innovation;
- The program facilitates appropriate reporting structures to facilitate the establishment of a portfolio of learning, which is required for future professional registration; and
- The program is finally, dynamic to support logical updates in cognizance with the changing imperatives within the industry as well as in support of reported professional co-operative education literature based on precepts of other best practices.

Documents developed and currently in use are presented in the Appendix.

DISCUSSION

The program in its uniqueness in South Africa within the electrical power engineering environment has no current academic references other than the broad precepts of current good practice within accepted co-operative education literature. The author supports and argues the veracity of this program in terms of the feedback obtained from other parties in our tri-partite association in this cooperative initiative. Against this, one must consider successes and objection within our program as being primarily subject to the individual trainee's innate interests and capacities to successfully conduct the work-integrated learning in industry.

A simplistic exercise was conducted to ascertain the veracity of our program within context against predisposed reflective questions, with the feedback support ratings given as per Table 1. The data in Table 1 reflects the overall agreement/satisfaction ratings indicated as gauged from individual interviews and visitation reports. Gauging by reflections in training opportunities, where trainees were recruited from their local Universities of Technology, we are confident to report a major shift in work placement opportunities offered to trainees in our department. This shift for instance, has seen more of our trainees being offered work placement opportunities in the mining and power generation sectors.

TABLE 1
Stakeholder perceptions of the Department of Electrical Power Engineering Program at the Durban University of Technology

Respondent	Reflective questions posed on the program	Overall program support rating
Workplace Mentors	– Initial alignment of tasks and competencies in the workplace were problematic. – Additional administration of documents required. – Documents support and guide trainee to develop the required competencies.	Above 70 %
Workplace Trainees	– Adjusting to effective reporting on the working environment was challenging. – Additional administration of documents required. – Documents support and guide me to develop the required competencies. – I have developed a strong link between the theory and application in the working environment. – I have become confident in meeting the workplace challenges in technology, its adaptation and working ethos.	Above 80 %
Industrial Service Providers	– The program facilitates through its co-operative interaction, technical knowledgeable, career orientated technicians. – Successful trainees within this system are considered as a valuable technical human resource asset. – We would prefer to train technician within this competency based system. – We recommend this competency based system to other industrial service providers.	Above 80 %
Academic Assessors	– Additional administration of documents required. – Documents support and guide trainee to develop the required competencies. – Competencies presented in submitted portfolio documentation, align and or exceed the minimum academic requirements expected.	Above 80 %

Unfortunately no ideal program exists to exclude all challenges. Within each university of technology and its departments a minimum recommended and non-prescriptive policy applies to work-integrated learning programs and procedures. The following challenges have been identified:

- Acceptance of our program to the wider universities of technology movement. Due to academic autonomy of universities of technology and their individual departments, no prescription is mandated in developing or assessing competencies within any current work-integrated learning program. With our departmental exception, the existing simplistic system remains in force in other engineering departments at the Durban University of Technology and all other universities of technology. Our conclusion is that the simplistic system meets the minimum requirements associated with academic workloads in administration and hence in favor by administratively burdened academics; and
- Discussion with higher academic authorities and professional societies. Discussions with regulatory higher academic authorities and professional societies have not materialized as expected. The situation is exacerbated by the lack of bi-lateral communication and administrative procedures involved in the presentation of any revised system for wider discussion. It is hoped that future discussions with the South African Society of Cooperative Education will be encouraging and supportive of the rationale and precepts of our unique system in electrical power engineering.

IMPLICATIONS AND CONCLUSIONS

The paper presented in terms of competency development obviously has further implications in that the program presented here could be adapted to suite most academic programs to facilitate competency based outcomes that are measurable against a known standard. Issues surrounding the assessment of developed trainee's competencies require further in-depth research as these are currently only aligned against the South African Qualifications Framework outcomes. A future exercise would be to provide data for analysis in gauging the correlation and effectiveness of how the developed competencies align with work-place expectations in the industry.

The greatest current challenge in South Africa is however in providing quality technical education against the backdrop of popular politically motivated fast track programs which are nationally proposed to meet the continued flight of technology. It is the author's firm belief that the system as presented in this paper supports the notion that engineering competence can be developed locally through innovative cooperative education programs.

In conclusion the author is appreciative of the opportunity to present arguments in the development and in support of a competency-based engineering cooperative education system that has been implemented in South Africa.

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APPENDIX

The program documents may be obtained from the Volume 10 Table of Contents.

ABOUT THE JOURNAL

The Asia-Pacific Journal of Cooperative education (APJCE) arose from a desire to produce an international forum for discussion of cooperative education issues for practitioners in the Asia-Pacific region and is intended to provide a mechanism for the dissemination of research, best practice and innovation in work-integrated learning. The journal maintains close links to the biennial Asia-Pacific regional conferences conducted by the World Association for Cooperative Education. In recognition of international trends in information technology, APJCE is produced solely in electronic form. Published papers are available as PDF files from the website, and manuscript submission, reviewing and publication is electronically based.

Cooperative education in the journal is taken to be work-based learning in which the time spent in the workplace forms an integrated part of an academic program of study. Essentially, cooperative education is a partnership between education and work, in which enhancement of student learning is a key outcome. More specifically, cooperative education can be described as a strategy of applied learning which is a structured program, developed and supervised either by an educational institution in collaboration with an employer or industry grouping, or by an employer or industry grouping in collaboration with an educational institution. An essential feature is that relevant, productive work is conducted as an integral part of a student's regular program, and the final assessment contains a work-based component. Cooperative education programs are commonly highly structured and possess formal (academic and employer) supervision and assessment. The work is productive, in that the student undertakes meaningful work that has economic value or definable benefit to the employer. The work should have clear linkages with, or add to, the knowledge and skill base of the academic program.

INSTRUCTIONS FOR CONTRIBUTORS

The editorial board welcomes contributions from authors with an interest in cooperative education. Manuscripts should comprise reports of relevant research, or essays that discuss innovative programs, reviews of literature, or other matters of interest to researchers or practitioners. Manuscripts should be written in a formal, scholarly manner and avoid the use of sexist or other terminology that reinforces stereotypes. The excessive use of abbreviations and acronyms should be avoided. All manuscripts are reviewed by two members of the editorial board. APJCE is produced in web-only form and published articles are available as PDF files accessible from the website http://www.apjce.org.

Research reports should contain; an introduction that describes relevant literature and sets the context of the inquiry, a description and justification for the methodology employed, a description of the research findings-tabulated as appropriate, a discussion of the importance of the findings including their significance for practitioners, and a conclusion preferably incorporating suggestions for further research. Essays should contain a clear statement of the topic or issue under discussion, reference to, and discussion of, relevant literature, and a discussion of the importance of the topic for other researchers and practitioners. The final manuscript for both research reports and essay articles should include an abstract (word limit 300 words), and a list of keywords, one of which should be the national context for the study.

Manuscripts and cover sheets (available from the website) should be forwarded electronically to the Editor-in-Chief directly from the website. In order to ensure integrity of the review process authors' names should not appear on manuscripts. Manuscripts should include pagination, be double-spaced with ample margins in times new-roman 12-point font and follow the style of the Publication Manual of the American Psychological Association in citations, referencing, tables and figures (see also, http://www.apa.org/journals/faq.html). The intended location of figures and diagrams, provided separately as high-quality files (e.g., JPG, TIFF or PICT), should be indicated in the manuscript. Figure and table captions, listed on a separate page at the end of the document, should be clear and concise and be understood without reference to the text.