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Towards a new engineering education policy for South African Further Education and Training (FET) colleges: easy articulation to universities and technikons and recognition by the Engineering Professional Council of South Africa

Zola Mbanguta

National Department of Education
Pretoria, South Africa

ABSTRACT: South African Further Education and Training (FET) colleges have historically been offering Trimester N-Stream knowledge-only trade-based programmes, which are very narrow in content as they have been designed to meet the needs of manual *low-skills-low-wages* industries. This situation has required urgent attention as these programmes have not changed over time in alignment with the current industrial technological and economic trends. This article gives a brief background of such programmes offered by FET colleges, critically reviews related literature, explores the action research methodologically-based functions of the National Engineering Education Task Team and the effects of its recommendations to the National Minister of Education towards an engineering education policy for South African FET colleges. The paper concludes by emphasising the commitment of taking FET college engineering education programmes towards a new level to make them acceptable to universities, technikons and the engineering profession for the improved recognition of an engineering artisan status within the engineering profession in South Africa for easy articulation to the engineering technician status or category.

INTRODUCTION

Apprenticeship-based engineering education at technical institutions in South Africa can be traced back to the 1880s during the country's industrialised expansion through mining and railway works, whereas apprenticeship training in the fields of agriculture, skilled trades or art and domestic service, had already started in the four provinces of South Africa. Apprenticeship training had been recognised through the promulgation of the Natal's Rights and Duties of Master, Servants and Apprenticeship Act of 1850, which was then followed by the Cape of Good Hope Law No.15 of 1856, Transvaal Law No.13 of 1880 and Orange Free State Master and Servants Ordinance No.7 of 1904.

In 1883, formal technical institutions were established in Kimberley, Johannesburg and Natal for the direct support of the mining and railway industries. Kimberley was later transferred to, and expanded, in the Cape. The formal technical education examinations legislation was promulgated in 1916 and the first group of students sat for their examinations in the same year. The National Apprenticeship Act of 1922 made, for the first time, provision for the training of artisans in the engineering field in boot making, building, clothing, carriage building, electrical engineering, furniture, leather working, mechanical engineering, mining and printing. Formal technical classes were attended at technical institutions for theoretical instruction, while practical training was realised in industry.

The promulgation of the Advanced Technical Colleges Act of 1968 was followed by the declaration of Colleges for Advanced Technical Education (CATES), which later became Technikons (institutions of higher education) in 1978. Technical institutions divorced themselves from technical colleges, which continued with the artisan training programmes at N1-N3 levels whilst introducing N4-N6 levels (tertiary) leading to the award of a National Diploma in Engineering. The National Diploma, with specific subjects and industrial or mining training requirements with examinations, leads to certificated engineers in industry or mining. Very few candidates qualify for and succeed in this examination to become certificated engineers. However, this did not last long as many employers started upgrading their own in-house training programmes and developed regional training centres after the promulgation of the Manpower Training Act of 1981, which also barred the training of full-time college learners [1][2].

STATEMENT OF THE PROBLEM

Further Education and Training (FET) college engineering education programmes have become very narrow in content as they were designed to satisfy employer needs and offer no practical aspect of the trade, while the majority of learners enrolled at these colleges are no longer apprentices. These trimester-based programmes have moved away from *education* and are not recognised by universities for learners' articulation, while technikons also have difficulties in their recognition for articulation.

Employers also refuse to recognise these qualifications because national policy does not enforce the practical and work experience aspects. The Engineering Council of South Africa is also making a demand that the FET college engineering education curriculum be reviewed for recognition by the profession as the present qualifications confine graduates to operators and repairers or maintenance personnel status or category, since the learning outcomes do not allow for progression towards registration as engineering technicians, professional engineering technologists and professional engineers. The higher education (N4-N6) levels of these programmes fall outside the binary model of higher education as promulgated in South Africa's Higher Education Act of 1997 [3].

RATIONALE FOR CHANGES AND AIM

The White Paper on Education and Training of 1995 aimed to introduce an integrated approach to education and established the South African Qualification Authority (SAQA) [4]. The SAQA's main function was to put into place the National Qualifications Framework (NQF). This aims to:

- Integrate education and training and enhance the quality thereof.
- Create an integral national framework for learning achievements.
- Facilitate access to, and mobility and progression within, education, training and career paths.
- Accelerate the redress of past unfair discrimination in education, training and employment opportunities.
- Contribute to the full personal development of each learner and the social and economic development of the nation at large.

The new South African understanding and definition of a qualification, as stipulated by the NQF and supported by the FET Act, the White Paper of 1998 and Skills Development Act of 1998, requires that the engineering education qualification should comprise fundamental, core and elective learning that should be underpinned by critical cross field and developmental outcomes [5-7]. The new outcomes-based education system also has some implications on the FET College engineering education qualification.

This article aims to interrogate *education* and the work experience components with regard to the NQF requirements required for these engineering education programmes on the basis of global practices for easy articulation to universities and technikons. This will increase their relevance to industry and the engineering profession in South Africa. The article also makes recommendations for a newly proposed FET college engineering education qualification, as well as teaching and learning strategies in South Africa.

EDUCATION AND WORK EXPERIENCE FOR FET COLLEGE ENGINEERING EDUCATION PROGRAMMES

In line with the Ministers of Education and Labour (2001) that, in terms of the South African Human Resource Development Strategy, people will be provided with a solid educational foundation for social participation and also be empowered to develop relevant and marketable skills at further and higher education levels [8]. Regarding the higher education institutions' call for a review of FET college engineering education curriculum, Bobbitt states that effective curriculum necessitates the clear formulation of specific instructional objectives and that the educator's leading task is to study life so as to discover the abilities, habits, appreciations and forms of knowledge that humans need; these would form the objectives of a curriculum that would be based on the skills needed for their attainment [9][10].

Silberman suggests that on the design and development of any education and training programme that is more likely to result in a lasting change, the cognitive, psychomotor and affective learning domains should be incorporated [11]. He defines the cognitive goals as being the priority where there is a lack of knowledge as they include the acquisition of information as concepts related to the programme content, the psychomotor goals as the priority where there is a lack of skills as they develop competence in the actual performance of procedures, operations, methods and techniques, and the affective goals as the priority when there is a lack of desire to use new technology or skills as they involve the formation of attitudes, feelings and preferences. Huitt agrees by stressing that the three behavioural objectives should include what he terms as learner behaviour, conditions of performance and performance criteria [12].

For successful curriculum planning, delivery and instruction, the three learning domains should take the lead as the cognitive learning domain, which is knowledge or mind-based, has three practical instructional levels of *fact*, *understanding* and *application* and the delivery mode is through a lecture or presentation [13]. The psychomotor learning domain, under which the learner is obliged to produce a product, has three practical levels of *imitation*, *practice* and *habit* and the delivery mode is through demonstration that is proficiency building in nature [14]. The affective learning domain is based upon behavioural aspects and may be termed beliefs, has five levels of *receiving*, *responding*, *valuing*, *organisation* and *characterisation by value*. Delivery mode is through discussions and affective checklists [13].

The current practice of FET colleges' engineering education programmes' lack of fundamental learning, critical cross field and developmental outcomes is a very serious flaw that should be rectified by simply adopting the NQF basic principles of a qualification. This is supported by global practice [15-18]. Fundamental to the critical cross field and developmental outcomes are the advancement of problem identification and solving skills, scientific and technological skills and critical and creative skills [5][7][19]. This is agreed to by Huitt, as well as Thomas and Smoot; the movement to the information age has focused attention on good thinking as an important element of life success and this would require new outcomes of critical and creative thinking as a focus of education [20][21].

Huitt argues that in critical thinking the application of cognitive processes to evaluating arguments and making decisions is studied, as it is more linear and serial, more structured, rational, analytical and more goal-oriented [22]. The generation of ideas and alternatives that do not fit the norm is studied in creative thinking, as it is more holistic and parallel, more emotional, intuitive, creative, visual, tactual and kinaesthetic [22][23]. This distinction corresponds to what Springer and Deutsch refer to as left-brain thinking (analytical, serial, logical and objective) and right-brain thinking (global, parallel, emotional and subjective) [24].

It is at this level of development on the part of the learner that self-regulation, which is underpinned by an accurate self-assessment of what is known and/or not known, develops [25]. Paris and Winograd believe that the notion of self-efficacy captures the essential features of metacognition in self-appraisal and self-management [26]. It is at this point of making judgements about what one knows or does not know in accomplishing a task that Kluwe introduces the metacognitive procedural knowledge through the executive monitoring and executive regulating processes [27]. This corresponds with Flavell's metacognitive strategies and Brown's metacognitive skills [28][29]. Kluwe defines the executive monitoring processes as involving one's decision to identify the task on which one is currently working, check on the current progress of that work, evaluate that progress and predict what the outcome of that progress would be. The executive regulating processes involve one's decision to allocate one's resources to the current task, determine the order of steps to be taken to complete the task and set the intensity and the speed at which one should carry out the task [27].

Engineering design education that is based on constructivist learning theory suggests that learning occurs in a project-based situation that is at once (in an integrated manner) authentic, supportive of the learning process and scaffolded. FET college education in South Africa has been, and continues to be, *education* rather than *industry-led* while vocational training, on the other hand, has developed as part of an industry-based project [30].

However, the interrelatedness of the state, college faculty and learners cannot be overemphasised [31]. Educational reform strategies emphasise the pedagogical benefits of linking structured work experience to academic or classroom work [32]. This link should be based on nationally agreed standards that promote the flexibility and portability of learners' skills across occupations, industries and geographic areas whilst improving the fit between college, work and the economy [15][33].

Work experience initiatives that allow learners to observe and participate in local workplaces and then reflect on their experiences introduce unique pedagogical opportunities and challenges. Gaining first-hand experience in a range of workplaces, such as from worker co-operatives to more highly bureaucratic organisations, may provide more authentic opportunities to critically examine the world of work than could be provided in contrived and sheltered college-based settings [34].

The integrated academic and industry-based education system makes education more meaningful to learners, thus reducing juvenile delinquency while lowering the drop-out rate and provides a better workforce to meet industrial and economical needs [35][36]. Critics of this concept raise almost the same concerns initially raised by Dewey [37][38]. Such concerns include that it takes the interests of the learners away and makes them subservient to the interests of the employers [32].

In some situations, work experience is linked to coherent programmes of study in which it aims to deepen the understanding of scientific and technological processes or of social organisations at work by means of practical participation and observation. In other situations, it aims to enhance learner motivation by showing them the relevance and the practical application of subjects they are learning at the college [39].

Benett suggests that learners on work experience should be under supervision [40]. He suggests that the planning for supervised work experience should encompass the whole sequence of activities that includes pre-placement and post-placement activities and the likely impact of individual interaction in that sequence of activities. He insists that work experience should provide opportunities for learners to develop the ability to solve problems and make decisions.

METHODOLOGY AND FINDINGS

As outlined previously, the research arose out of the newly promulgated legislation and released policies on FET college engineering education in South Africa. Also having analysed the problem statement and having stated the aim of the paper, the general approach to the research was considered.

The General Approach

Action research, case study, interviews and questionnaires were used over a four-year period of research. McNeill alludes that it has become perfectly accepted to use a variety of research techniques in one research task. This perception is supported by Trow and quoted in Burgess that:

> *Let us be done with the arguments of participant observation versus interviewing, as we largely dispersed with the arguments for psychology versus sociology, and get on with the business of attacking our problems with the widest array of conceptual and methodological tools that we possess and they demand* [41].

In this research, action research was used as the main method; hence, it is small-scale intervention in the functioning of the real world while it allows for a close examination of the effects of such intervention. According to Cohen and Manion, action research is situational, collaborative, participatory and self-evaluative [42]. Zuber-Skerrit describes action research as a critical and self-critical collaborative enquiry by reflective practitioners being accountable and making the results of their enquiry public. It is important that the practitioners evaluate their practice themselves and engage in participatory problem-solving and continuous professional development [43].

The Ministerial Framework Committee on Engineering Studies identified the problem in this research paper and developed a plan of critically informed action to improve what was already happening, guided by Kemmis and McTaggart on the four fundamental aspects in action research [44]. The next step was to implement the plan. The first step of action was taken in September 1997 for the recommendation to the Minister of Education to approve a prototype, funded by the partnership between South Africa and Germany, in the integration of education and training whilst testing the introduction of fundamentals in the form of communication and computer studies. The Minister granted permission for the prototype in June 1998.

During the period between September 1997 and June 1988, as the Ministerial Curriculum Policy structures, which constituted the Coordinating Committee on Vocational Education and Heads of Education Committee (HEDCOM), indicated their support on the idea, a task team appointed to manage the prototype nominated Germiston College for the prototype. The theoretical classroom was changed to make it suitable for the demonstration and application of knowledge for effective cognitive and psychomotor learning goals. Positive affective goals were achieved by installing modern equipment, retraining educators for an integrated knowledge and application curriculum and assessment, training of verifiers, gaining industry support for their involvement in the curriculum development processes, including accreditation of the College and providing work experience opportunities to learners, development of unit standards and provisional registration thereof with the SAQA and development of the electrical engineering NQF Levels 2-4 learning programmes. New recruits were admitted into the new electrical engineering NQF Level 2 programme in July 1998.

The observation step of the action research began and the Germiston College prototype became the case study to be observed. The purpose of the case study was to probe deeply and to analyse intensively the multifarious phenomena that constitute the lifecycle of the particular unit of study with a view to establishing generalisations about the wider population to which that unit belongs. Merrian states that the other main strengths of the case study are that it can also be used to study a phenomenon systematically, to conduct a survey and to analyse data gathered by survey instruments [45].

Cohen and Manion suggest that the knowledge of the ways in which learners can learn and the means by which education and training institutions achieve their goals should be verified, built upon and extended by case studies [42]. The observation step of action research becomes a technique on its own. Its major advantage is its directness as one does not need to ask people about their views, feelings or attitudes but only to watch what they do and listen to what they say. This is as opposed to other techniques that are known for their notorious responses and discrepancies between what people say they have done or will do and what they actually said and did [46-50]. This should be recorded in some way to enable the description, analysis and interpretation of the observation [51].

After four months of the prototype progression, it became clear that the teaching and learning process in engineering education had changed as the four building blocks of cognitive apprenticeship instruction were applied in the form of content, method, sequencing and sociology [52-55]. This strategy delivered powerful learning that was relevant to the workplace in an education and training institution. It was found compatible with learning the generic skills of the modern workplace. It became clear that the trimester system, on which engineering education programmes are based, is a very short period of time for *education* programmes as they have to incorporate integrated knowledge and application and fundamentals underpinned by the critical cross field and outcomes and work experience.

The research team disseminated the data collected to the rest of the colleges in the country and sought their opinions through a questionnaire. The questionnaire informed colleges of the new lessons learnt from the prototype. These supported the NQF principles that fundamentals and work experience, underpinned by the critical cross field and developmental outcomes, be part of a new engineering education qualification. The questionnaire also attempted to find out the amount of support the newly envisaged qualification might have from colleges. The results are detailed below.

Eighty engineering education colleges were contacted, with 66 colleges responding. The major findings were:

- 100% supported the shift from a trimester-based programme to a SAQA-approved qualification by introducing the fundamentals underpinned by the critical cross field and developmental outcomes.
- 60.6% were already receiving accreditation of the practical component from Industry Training Boards.
- 32% provided work experience to their learners, although the rest supported that the work experience component be enforced in the National Curriculum Policy.
- 18.2% were involving learners in college-run business enterprises under the Technopreneurship Programme promoted by the Department of Trade and Industry.
- Out of the 20 Industry Training Boards, 19 were involved with college education in one form or another.

At the reflection step of action research, the research team then gave advice based on the data collected and lessons learnt from the prototype to the Minister of Education. At the same time, a recommendation was made for the approval of a *Policy on the Shift from Trimester Based Programmes to South African Qualifications Authority Approved Engineering Education Qualifications at FET Colleges in South Africa*. Regarding fundamentals, the subject of Communication Studies was replaced by two Languages for Schools. The Minister approved the policy on 25 March 1999.

Parallel to the Minister's approval process, the research team made recommendations to HEDCOM for the approval of the broadly-based curriculum on engineering education, which was opposed to the traditional narrow curriculum. HEDCOM approved the broad curriculating of FET college engineering education programmes on 12 April 1999.

In July 1999, the revision and modernisation of FET engineering education programmes was underway with the main objective of making these programmes acceptable to universities, technikons and the engineering profession. The research team's terms of reference were reviewed and the new task of developing engineering education learning outcomes that would lead to the development of unit standards and new engineering education qualifications, and registration thereof with the SAQA, was in progress.

RESULTS AND FINDINGS

As the research team's intended outcome was to develop a product acceptable to the universities, technikons, industry and the Engineering Council of South Africa, the process was designed in such a way that representatives from these sectors played a leading role. The research team's terms of reference was to redesign FET engineering education programmes that would address the needs for quality engineering education for all, the needs of the disadvantaged and the broadening of the FET engineering education curriculum for entry into the world of work and higher education and professional recognition.

The recommendations that have been made for both the NQF Levels 2-4 and NQF Level 5 (higher education programmes) are presented below.

1. Mbanguta states that for the NQF Levels 2-4 [56]:

   The research team agreed unanimously on the following engineering education disciplines as the priority:

   - Aeronautical engineering.
   - Automotive engineering.

- Civil engineering (building projects with ecological technology) and (infrastructure building).
- Clothing design.
- Computer engineering (information and media technology) (after the release of the Information and Communications Technology Policy by the Minister in 2001).
- Design engineering/technology.
- Electrical engineering.
- Electronics engineering.
- Mechanical engineering.
- Metallurgical engineering.
- Mining engineering.

For the completion of an engineering education qualification, fundamentals in the form of two languages and information and communications technology will be added to the above disciplines. Electives will include physical science, mathematics, design engineering and technology, business management and economics and will also be added to the above disciplines.

The agreed definition of an engineer was a person who is specifically trained and experienced in planning, developing and supervising projects that bring about changes and development, as he/she is concerned with the practical application of scientific knowledge to the solution of real world problems that are based on skills requiring knowledge of what has been learnt in the past, the adaptation of information from seemingly unrelated areas and the continued search for new and better methods to solve problems. Based on this definition, the following learning outcomes were agreed to:

- *Engineering Knowledge*: Demonstrate an understanding of applicable concepts, principles and contested knowledge in the relevant engineering discipline and also demonstrate an understanding of the engineering industry, its applicable structures, processes, terms and concepts.
- *Engineering Contexts*: Demonstrate an understanding of how knowledge in engineering and skills impact on the management of natural resources, cultural values and socio-economic development.
- *Engineering Values*: Demonstrate an understanding of the dynamic, contested nature of engineering knowledge and the need to interpret its application in terms of ethical considerations.
- *Engineering in Action*: Demonstrate an understanding in identifying materials and the basis for material selection used in processes, manufacturing and repairs in the specific engineering disciplines.
- *Quality Engineering Works*: Apply statutory requirements and quality systems, including evaluations of engineering work in processes of manufacturing, maintenance and repairs in engineering disciplines.
- *Engineering Principles*: Demonstrate an understanding of the dynamic proven principles of engineering knowledge.
- *Algo-Heuristics Strategies*: Demonstrate the acquisition of engineering knowledge by using research skills, problem identification and solving skills, critically evaluating information and transferring knowledge to new situations, and making responsible decisions, thus developing attitudes, beliefs and values.
- *Engineering Project*: Plan, design, develop and supervise an engineering project.

The agreed definition of engineering education is the study and application of scientific principles and technological knowledge and skills through a rationale designed process in a specific and relevant industry approved learning environment, which results in a permanent change in learners' attitudes, beliefs and values, thus improving the quality of life. Based on the above agreed learning outcomes and underpinned by this definition of engineering education, the Engineering Artisan category is proposed for recognition by the Engineering Council of South Africa, through the South African Institute of Artisans, in terms of the Engineering Professions Act of 1990 in addition to the following categories:

- Professional engineer.
- Professional engineering technologist.
- Certificated engineer.
- Engineering technician.

2. Research on the German Master Artisan Education and Training Programme should be undertaken in collaboration with the Engineering Council of South Africa, Institute of Artisans and relevant Sector Education and Training Authorities. This will be to strengthen the future of engineering artisan education and training in South Africa.

3. Mbanguta recommended that for the NQF Level 5 (higher education programmes), some FET colleges are already in a position to offer the technikons' National Certificate and Higher National Certificate engineering education programmes [57]. This is based on the FET college/ technikon subject equivalents that lead to a full programme and qualification (see Table 1).

   Pretoria College/Pretoria Technikon Partnership Agreement on Engineering Education

   However, for the completion of a full engineering education qualification, the technikon qualifications already registered with the SAQA should be followed as they are also recognised by the Engineering Council of South Africa and lead towards the engineering technician category.

4. The suggested teaching and learning strategy is a cognitive apprenticeship-based approach built on the four building blocks of content, method, sequence and sociology. They are underpinned by the following theories of learning:

   - Bloom's Taxonomy of educational objectives, which are based on cognitive, psychomotor and affective learning.
   - Constructivist theory of learning.
   - Landamatics theory of learning based on the snowball method.
   - Landa's Algo-Heuristics theory.

Table 1: Comparison of FET college subjects and the corresponding technikon subject.

FET College Subject	Technikon Subject
Mathematics N4 and N5	Mathematics I
Mathematics N4, N5 and N6	Mathematics I and II
Engineering Science N4 and Mechanotechnics N6 (plus laboratory practicum)	Mechanics II
Engineering Drawing N4 or Mechanical Draughting N4	Engineering Drawing I
Mechanotechnics N4 and Machines and Properties of Metals N4	Mechanical Manufacturing Engineering
Fluid Mechanics N5 (plus laboratory practicum)	Fluid Mechanics II
Electrotechnics N4 and N5 (plus laboratory practicum)	Electrotechnology I
Electrotechnics N4, N5 and N6	Electrotechnology II
Computer Practice N4	Computer Principles I
Mechanical Drawing and Design N5 and N6	Mechanical Engineering Design
Strength of Materials and Structures	Strength and Structures
Power Machines N5 and N6	Thermodynamics II

CONCLUSIONS

We have inherited a skewed system of education that has always been biased towards academic education and that has relegated FET college engineering education to the status or category of *industrial machinery operations and repairs*. The South African 32:1 ratio of engineers produced per annum by higher education institutions per million of the population is not a true reflection of the engineering infrastructural development in this country [58]. To a great extent, this development could also be attributed to artisans in the engineering profession, yet they find themselves in difficult circumstances that isolate them from continuing to universities and technikons and are refused professional recognition and registration by the engineering profession on the basis of their FET college education status [59]. On the basis of the implementations of the above recommendations, this situation would improve instantly.

At the dawning of the 21st Century, may we witness the continued movement of FET college engineering education towards the engineering profession and ultimately taking its rightful place by shedding off the *unpopular narrow N-Stream trade theoretical-based studies*, which have had very bad connotations in South African society? We may also then witness the phasing in of engineering education based on international practices that will enable learners to access universities and technikons directly, whilst also being recognised by the engineering profession.

The alignment of FET college engineering education learning outcomes to higher education in ascertaining easy articulation, and the offering of Technikons' National Certificate and Higher National Certificate (NQF Level 5) engineering education programmes that will be planned, funded, accredited and quality assured by the Council on Higher Education/Higher Education Quality Committee would be a step towards the rectification of the *inverted pyramid of the SA higher education system*. This will bring higher education out of the ivory towers to make it available to all at a very affordable cost [60].

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