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Towards an outcomes-based teaching and learning module for teacher preparation programmes of FET institutions' engineering and technology educators in South Africa

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ABSTRACT: Outcomes-Based Education (OBE) was adopted as a national policy for teaching and learning in South Africa to replace the traditional rote learning in the national education system. This has placed a high level of demand on the new teacher preparation programmes for Further Education and Training (FET) institutions' engineering and technology education programmes, which have historically separated knowledge and its application or theory and practice. This article gives a brief background of the existing teacher preparation programmes for engineering education that are currently offered by South African technikons, critically reviews related literature, explores the research methodology that was used to test the views of educators and learners at FET institutions on the traditional rote learning versus OBE as a new teaching and learning method, and presents the results and findings. The article concludes by making recommendations for a new teaching and learning module or subject that is underpinned by relevant educational epistemologies and that will support Outcomes-Based Education for teacher preparation for FET institutions' engineering and technology education programmes.

INTRODUCTION

Higher education in South Africa has a series of goals implicit in its philosophy, one of which is to develop human resources for social regeneration and economic development [1][2]. South African educational analysts perceive higher education as being at the crossroads [3]. This is due to the fact that South Africa is currently facing a grave shortage of professional engineers, professional technologists, certificated engineers, engineering technicians and engineering artisans [4-8].

The fundamental reason for this situation is the history of the South African higher education system, which has always been biased towards a specific population group, especially with regard to engineering and technological education. A call was made for careers for all and if the fruits of this call are to benefit every South African, then higher education, with specific reference to engineering and technology education, should be brought out of the ivory towers and be made available to every South African [9].

South Africa requires a high standard of engineering and technologically trained teachers in order to stimulate viable economic growth, based on an educational strategy for the development of creative and critical thinking skills, rather than rote learning [3]. Reddy emphasises this point by stating that the economic growth of any country is directly proportional to its appropriate education system [10].

The South African Department of Education emphasises that universities, technikons and colleges should educate people directly or indirectly for entry into occupations [11]. The various levels and foci of technical and vocational education and training should take into account the rapid changes in national and international technological trends.

The severe shortage of well prepared teachers for Further Education and Training (FET) institutions' engineering and technology education is one of the most serious problems confronting the higher education system in South Africa today. This shortage not only hampers development but also increases inflation and relative deprivation in South Africa [3][12].

A well prepared teacher for FET institutions' engineering and technology education has a prominent role to play in the education of youth. The teacher provides skills training that directly raises societal living standards and contributes to job opportunities required by the economy in the following disciplines:

- Aeronautical engineering;
- Automotive engineering;
- Civil engineering;
- Computer engineering (information and media technology);
- Design technology;
- Electrical engineering;
- Electronics engineering;
- Mechanical engineering;
- Metallurgical engineering;
- Mining engineering.

The above engineering disciplines should be underpinned by stipulated exit learning outcomes at the further education and training level [13].

BACKGROUND TO TEACHER PREPARATION FOR FET INSTITUTIONS IN SOUTH AFRICA

There are quite a large number of higher education institutions offering academic teacher education, as compared to those few that offer technical teacher education. Twenty universities provide contact teacher education through their departments, faculties or schools of education. In 1995, there were 28,954 student teachers in South Africa [1].

Presently, there are 15 technikons in the country. Five out of the 15 existing technikons offer teacher education, including teacher preparation for engineering education. These technikons cater for 1,846 students [14]. Table 1 indicates the statistical number of technikons involved in technical teacher education.

Table 1: Statistics of technikons providing teacher preparation programmes in engineering education [1].

Province	Total No. of Technikons	No. of HBT*	No. of HWT*
Kwa-Zulu Natal	2	1	1
Western Cape	2	1	1
Gauteng	1	1	0
Total	5	3	2

Note: HBT = Historical Black Technikons; HWT = Historically White Technikons

Outcomes-Based Education (OBE) was adopted as a national policy for teaching and learning in South Africa to replace the traditional rote learning in the national education system. There is a great need for FET institutions engineering and technology education programmes because of the new OBE Curriculum 2005 framework. This places a demand on the retraining of educators so that they can fit into the new system. Therefore, the role of technikons as providers of engineering and technology education becomes more important than ever before.

A relevant teacher preparation programme was developed to meet the demands of the industrial environment. This resulted in a new programme for technical teacher training that was developed by the technikons during the period from 1994 to 1995. The curriculum for the programme, which is known as National Diploma: Education: Technical, was implemented in 1996. The following section will outline the course structure of this programme.

NATIONAL DIPLOMA: EDUCATION: TECHNICAL (1996)

The National Diploma: Education: Technical course entails three years of full-time study at a relevant technikon and practical teaching of 10 weeks at technical high schools.

Admission Requirements

Admission requirements cover the Senior Certificate with a pass mark in physical science and mathematics or a recognised equivalent, eg N3, a pass mark in mathematics and engineering science and two other subjects plus two official languages of the Senior Certificate.

Course Structure

- First year:
  Fundamentals: Third Language I, English I, Theory of Education I, Teaching and Learning Media, Philosophy of Life and Life Skills, Teaching Practice I, and Educational Management I, plus:
  Majors: Mathematics (Education) I, Graphics (Education) I, and Technology (Education) I, plus:
  Didactics: Subject Didactics: Mathematics I, Subject Didactics: Technology I, and Subject Didactics: Graphics I.
- Second year:
  Fundamentals: With the exception of Teaching and Learning Media and with the addition of Computer Literacy, these offerings are the same for first and second levels.
  Majors: Mathematics (Education) II, Graphics (Education) II, Technology (Education) II, plus:
  Two of the following: Subject Didactics: Mathematics II, Subject Didactics: Technology II, and/or Subject Didactics: Graphics II.
- Third year:
  Fundamentals: Except Third Language II and English II, students have to do Level III of the subjects mentioned in second year at Level III, plus:
  Majors: One of the relevant engineering disciplines, plus:
  Two of the following: Subject Didactics: Mathematics III, Subject Didactics: Technology III, and/or Subject Didactics: Graphics III [1].

After completing the three-year programme, students can continue to study further in a postgraduate course. The one-year full-time postgraduate course would then make the whole three-year and one-year programme a BTech degree programme.

BTECH: EDUCATION: TECHNICAL

This course was developed during 1996-1997. The course entails one year of full-time training and is also offered by technikons.

Admission Requirements

Admission requirements cover the National Diploma: Education: Technical with an average of 60% in the final year. Alternatively, prospective students can have a three-year qualification that the senate approves, with or without additional requirements, as being of equivalent standing. Candidates who did not follow the ND: Education: Technical programme have to do a bridging course, which is incorporated in the BTech: Education: Technical programme.

Candidates have to pass the following subjects before being awarded the BTech qualification:

- Fundamentals: Theory of Education IV; Educational Management IV and Research Methods and Techniques.
- Three Majors from: Relevant Engineering Discipline, Mathematics (Education) IV, Graphics (Education) IV and/or Technology (Education) IV.
- One Didactic from: Subject Didactics: Mathematics IV, Subject Didactics: Technology IV or Subject Didactics: Graphics IV [1].

RESEARCH STUDY

Problem Identification

The quality of teacher preparation programmes for FET institutions' engineering and technology education offered by technikons in South Africa have related problems. These problems include fragmentation and over-emphasis on theoretical content at the expense of practical applications. This results in an overloaded curriculum, among other things.

Aim of the Study

The study aims to make a recommendation for a teaching and learning method that integrates the knowledge and its application approach in support of Outcomes-Based Education for teacher preparation programmes on FET engineering and technology education in South Africa.

Research Question

What are the pertinent factors involved in the preparation of teachers for FET engineering and technology education within Outcomes-Based Education?

STUDY RESEARCH METHODS AND PROCEDURES

Having analysed the problem statement and research question, the researchers considered the following:

- General approach to the study.
- Population and sampling strategy.
- Instrumentation.
- Data collection and analysis.

General Approach to the Study

Yin recommends that both the historical and case study research methods are excellent tools as researchers are able to deal with the past and a full variety of evidence in the form of documents, artefacts, questionnaires, interviews and observations [15].

Population and Sampling Strategy

Miles and Huberman suggest that, after developing a sampling strategy, sampling tends to be more purposive than random in qualitative research because all facets of an important problem cannot be studied during one study [16]. Therefore, it is most important to take note of the following aspects:

- Who is to be observed and data collected from?
- In which settings is the data to be collected?
- When and at what times is the data to be collected?
- Which events, activities or processes are to be observed [17]?

As the study was concerned with identifying factors within Outcomes-Based Education that are considered important in the preparation of teachers for engineering and technology education, it was considered important to obtain as much information as possible from the educators and learners involved in the teacher preparation programmes for engineering and technology education.

The sample consisted of three out of five technikons that offer teacher preparation for engineering and technology education in South Africa, two FET colleges and two technical high schools. The population consisted of 242 educators, in the ranks of Heads of Department (HODs), lecturers, teachers and learners who were selected from technikons, FET colleges and technical high schools.

The technikons involved in the study were: Cape Technikon, Eastern Cape Technikon and Technikon Northern Gauteng. The FET colleges involved in the study were Odi College and Mpulayeni College. The schools involved in the study were Soshanguve and Pretoria Technical High Schools.

The educators were experts in the engineering disciplinary contents and mastered the competencies and abilities of a properly qualified engineering educator. Learners were able to determine whether their needs were met during the education process since they also did teaching practice at FET colleges and schools.

Instrumentation

Questionnaires were used to collect the data as they are conveniently used to obtain data beyond the physical reach of the researcher is the questionnaire [18]. According to Tuckman a questionnaire is considered to be a relevant instrument of measurement, which could successfully reveal data about persons by asking them rather than observing their behaviour in a particular way [19]. The questionnaire was also used to obtain information about the participants' thoughts, perceptions, opinions, values and beliefs about the teaching and learning of student teachers [20]. The questionnaire used summated rating scale or Likert scale to measure abstract constructs.

The design of the questionnaire took into consideration the fact that the information obtained from the questionnaire responses formed the primary source of data. Therefore, consideration was given to the introduction, the format, the sequence of questions, the content of the questionnaire, the type of questions, the length of questions, the instructions and the cover letter as suggested by Wimmer and Dominick [21].

Two sets of questionnaires were developed: one set for the academic staff (HODs, lecturers and educators) and the other set for the learners. Their format is as follows:

- Introduction: The introduction to the questionnaires, contained in the covering letter, was brief and concisely worded to explain the purpose of the questionnaire to the respondents. The wording of the questionnaires was kept as clear as possible.
- Format: The questionnaire was carefully constructed. The format, design and typing of the questionnaire was given due consideration. Care was taken to ensure that the questionnaire did not appear cluttered and that time was not wasted in responding to questions.
- Sequence of questions: Consideration was given to the order in which questions were placed in the questionnaire. Personal and general questions were asked first, followed by specific ones. Questions were arranged clearly and in terms of sections and they followed each other in a logical sequence.
- Content of the questionnaire: The content of the questionnaire focused mainly on the teaching and learning activities employed for the technical training of the technical teachers. Although there were other questions, their primary aim was to get first-hand information

concerning the perceptions, understanding and opinions on those aspects considered important in order to keep abreast with the appropriate technology.

The Piloting of Instruments

As suggested by Oppenheim, every question, every question sequence, every inventory and every scale in the study was piloted on two HODs, two educators and five learners involved in the teacher preparation programme for engineering and technology education at Technikon Northern Gauteng [22]. This helped researchers to refine their data collection plans with respect to both the content of the data and the procedure to be followed, as suggested by Yin [23].

After this process, the questionnaires were modified and reviewed, while at the same time more probing questions were identified. The instrument validity was checked by using a panel of two experts to systematically examine the given content and evaluate its relevance to the specified case. The instrument reliability was also checked to ensure that the results of the study would be dependable through the triangulation method.

Data Collection and Analysis

The questionnaires were administered and posted to various institutions in provinces across the country. Institutions were first contacted by telephone before the permission letter and questionnaires were sent through the post. This process was undertaken to ensure the proper administration of questionnaires at the receiving institutions. The questionnaires were sent to institutions by certified mail postage system to ensure safety.

The researchers kept constant contact with the responsible persons telephonically to ensure a completed return of the questionnaires. The researchers also visited nearby institutions to request academic staff to complete the questionnaires.

The time taken to complete the questionnaires varied from one institution to another. Given the scope of the sample across the country, the procedure and administration of the questionnaires were regarded as successful.

Data analysis consisted of relating the questionnaire data and the information from the documentary study to the aim of the study and research question as outlined. The questionnaire data from each respondent was cross-referenced to the data from the other respondents. The findings were then written as reported below.

Results and Findings

The data collected were divided into sections: those from educators and the others from learners. A summary of the analyses of the data on important factors is presented in Table 2.

According to the findings reflected in Table 2, the majority of respondents regarded the following methodologies as being very important:

- Problem-solving (95%);
- Demonstration (88%);
- Project-based (94%);
- Team and individual work (89%);
- Technological process approach (96%).

DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

The findings presented here on the teaching and learning methodologies indicate that problem solving, working within a team and the technological process approach are highly supported by the study's respondents. The new South African Outcomes-Based Education (OBE) approach is underpinned by critical and developmental outcomes that include problem identification and solving skills, scientific and technological skills and creative and critical thinking skills [24-26].

Several researchers emphasise that the movement to the information age, which has conquered the entire globe, places much of its focus on new outcomes that are creative and require thinking skills [27][28]. They argue that the old standards of simply being able to score well on a standardised test of basic skills, although still appropriate, cannot be the sole means by which to judge the academic success or failure of learners. Huitt classifies the techniques used in problem solving and decision making into two groups that roughly correspond to the critical and creative thinking dichotonomy [29].

Demonstration and project-based approaches were scored highly by the respondents, clearly demonstrating the need for theories of learning that are relevant to the integration of knowledge and application approaches. Yamashiro suggests that the traditional-lecture versus contemporary-work-environment approach should always be borne in mind [30].

Landamatics theory, which has been applied to most training settings, recommends the snowball method as it applies to teaching a system of cognitive operations by teaching the first operation, then the second operation which is practiced with the first, and so on [31-33].

Table 2: Rating of relevant teaching and learning methods in the technical workshop or laboratory – according to the educators.

Teaching Methods Teaching and Learning Methodologies		Evaluation Scale					
		SD %	D %	A %	SA %	DNK %	Total %
1	Problem solving	-	4	51	44	1	100
2	Demonstration	-	12	55	33	-	100
3	Traditional Lecture	12	38	31	15	5	100
4	Project-based	-	6	50	44	-	100
5	Team and individual work	3	7	52	37	2	100
6	Technological process approach	-	10	37	49	4	100

Note: SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree, and DNK = Do Not Know

Collins, Brown and Newman suggest that engineering education that is based on the Constructivist theory offers effective learning. This is because it occurs in a project-based situation that is at once authentic, supportive of the learning process and scaffolded [34].

Cognitive Apprenticeship Model

Those systems of education that separate knowledge and its application have resulted in the delivery of a vocational curriculum that is irrelevant to industrial and economic needs, and that has limited the nation's productivity and its ability to raise living standards. As such, the researchers recommend for the introduction of the cognitive apprenticeship model, which is to be underpinned by Bloom's Taxonomy of educational objectives based on the cognitive, psychomotor and affective learning domains as the relevant teaching and learning method in order to support Outcomes-Based Education (OBE) [35][36]. This is has also been called for by Mbanguta for teacher preparation programmes on FET institutions' engineering and technology education in South Africa [7].

The new teaching and learning method will be introduced as a separate module or subject for all engineering and technology BTech (Technical/Technology) and BEd (Technical/ Technology) programmes.

Lerman and Pouncy, as well as Resnick, recommend for the employment of the cognitive apprenticeship model as a teaching and learning method in specific cases where education institutions use learning methods that differ enormously from the way people learn at work and in other life contexts [37][38].

The cognitive apprenticeship model has four main building blocks, namely:

- Content, which takes into account the domain knowledge, heuristic strategies, control strategies and learning strategies. This contends that the learning situations should focus exclusively on the concepts, the facts and the procedures of a subject.
- Method, which incorporates modelling, scaffolding, coaching, articulation reflection and exploration. This contends that the teaching methods should give the learners an opportunity to observe, to engage in and to discover expert strategies in context.
- Sequencing, which covers the deliberate decisions regarding the order of learning activities, global before local skills, plus increasing levels of complexity and diversity. This contends that learning should be staged so that the learner builds the multiple skills required in expert performance and discovers the conditions under which they apply.
- Sociology, which considers the social characteristics of the learning environments, the situated learning, the community of practice, the intrinsic motivation and the level of cooperation. This contends that the learning environment should reproduce the technological, the social, the time and the motivational characteristics of the real world situations where what is being learnt will be used. Many educators have discovered that the sociological elements of contextual learning are germane to teaching the higher levels of information, the troubleshooting and the application of diagnostic skills [39][40].

Assessment and possibly verification and quality assurance aspects within the module or subject will be addressed too.

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