(REVIEW ARTICLE)

# Theoretical models for evaluating engineering technology programmes in polytechnics in Nigeria

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## Abstract

Polytechnic education in Nigeria was established to champion the technological advancement of the nation. Consequently, products of polytechnic engineering technology programmes (graduates of engineering from polytechnics across Nigeria) are expected to receive quality training capable of developing their skills and competence for excellent industrial operations. One of the numerous ways of achieving effective engineering education in polytechnics across Nigeria is through quality appraisal of programme. Theories and models therefore are adequately utilized in carrying out proper evaluation of educational programmes. Therefore, understanding relevant theoretical models applicable in evaluating educational objectives is very necessary to achieving reliable results. Therefore, the essence of this study is to outline and discuss relevant theoretical models for evaluating polytechnic engineering technology programmes in Nigeria with the aim of assisting technology and engineering graduates, lecturers and researchers to work assiduously towards the technological advancement of the nation. Consequently, CIPP model, Outcome-based evaluation model and Kirkpatrick's model were key theoretical models discussed in this study.

## 1. Introduction

Theories entail conjecture, models, framework or body of knowledge and generalizations. Weick as cited in [1] submitted that theory is a continuum belonging to a family of words including guess, speculation, supposition, conjecture, proposition, hypothesis, conception, explanation and model. A theory thus includes statements having observational consequences [2]. Hence, theory consists of models that have observable relationships and applications to any given phenomenon under study. Several theoretical models applicable in TVET programme evaluation such as the Context, Input, Process and Product (CIPP) evaluation model, engineering model, psychomotor skills acquisition model, outcome-based evaluation model, Kirkpatrick's evaluation model, amongst others are applicable to engineering technology programmes offered in Nigerian polytechnics. The CIPP model in this context considered the study objectives which spelt out what polytechnic education in Nigeria was established to achieve of which is primarily the production of skilled manpower crucial for the nation's industrial development. This is what the context in CIPP implies in this study; the input in CIPP model referred to the polytechnic resources required to run effective polytechnic education in Nigeria; the process in CIPP model described the management of these polytechnic resources so as to achieve the stated objectives and finally, the product in CIPP model described the quality of graduates produced by polytechnics across Nigeria vis-à-vis the type of training they received with the available polytechnic educational resources and how the acquired skills enhance productivity in the world of work.

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Evaluation models are very crucial in assessing the psychomotor skills acquisition and utilization in Engineering and Technology programmes of tertiary educational institutions like polytechnics, universities and colleges of technology across the globe. Engineering technology programmes offered in polytechnics in Nigeria train students both in the theories and practice of engineering. Here, emphasis is given to the practical aspect of the training as this is what guarantees the acquisition of skills needed in the world of work for personal development of the graduate and subsequently, the technological development of the nation. In this study therefore, the CIPP model, outcome-based evaluation model and Kirkpatrick's evaluation model were reviewed specifically in tandem with the effectiveness and worth of engineering programmes offered in Nigerian polytechnics.

A polytechnic represents a non-university, higher learning institution saddled with the responsibility of offering different courses in technical subjects, technology, industrial production, agriculture, commerce and communication together with the provision of knowledge and skills associated with the handling of relevant tools and equipment, and to develop students through theoretical and practical experiences [3]. Polytechnic as described by [4] is an educational system that equips individuals for employment and self-reliance through adequate provision of all necessary skills needed for agricultural, industrial and commercial roles capable of accelerating the economic development of a nation. Similarly, the International Labour Organization (ILO) and United Nations Education, Scientific and Cultural Organization [5] described polytechnic education as a segment of the general education that prepares individuals for occupational fields and for effective participation in the world of work, life-long learning for responsible citizenship preparation, sustainable development promotion, a best method of facilitating poverty alleviation, and which also enables individuals to develop technical and entrepreneurial skills and attitudes. Polytechnic education is a planned programme of courses that begins with an exploration of career options, support for basic academic and life skills and achievement of higher academic standards, leadership, industrial work preparation and advanced continuing education [6]. In essence, polytechnic education involves knowledge accumulation and application which are two key factors in economic development. Similarly, [7] opined that polytechnic education would be of immense help in providing local manpower for the nation's industries thereby cutting down on over-dependence on foreigners for the industrial development of Nigeria. Some of the engineering technology programmes offered in Nigerian polytechnics which these theoretical models find application include electrical/electronic engineering, computer engineering, civil engineering, mechanical engineering, chemical engineering, oil and gas engineering technology among others.

Ideally, the essence of polytechnic education in Nigeria is to bring about the development of middle level indigenous manpower that would help in the advancement of the nation's industries through the acquisition of lifelong skills relevant to their chosen trade or vocation.

According to [8] the objectives of Polytechnic education are to:

- Provide full time or part-time courses of instruction and training in engineering, other technologies, applied sciences, business and management, leading to production of trained manpower.
- Provide the technical knowledge and skill for agricultural, commercial and economic development of Nigeria.
- Give training and impart the necessary skills for the production of technicians, technologist and other skilled personnel who shall be enterprising and self-reliant.
- Train people who can apply scientific knowledge to solve environmental problems for the convenience of man.
- Provide exposure to professional studies in these technologies.
- The policy also states that, in pursuance of these goals, government shall adopt measures to:
- Develop and encourage the ideals of Polytechnic Education through students' industrial work experience scheme.
- Improve immediate and long term prospects for Polytechnic graduates and other professionals with respect to their status and remuneration.

## 1.0 The CIPP Model

CIPP is an acronym for context evaluation, input evaluation, process evaluation and product evaluation. This model was developed by Guba and Stufflebeam in 1970 as a result of appalling conditions of Chicago inner-city schools. According to the CIPP model, evaluation is the systematic investigation of the value of a programme or other related variables [9]. The CIPP model takes into account, the end users of the evaluation results, how will they use them and to what aspects of the system are they applicable [9]. In essence, the CIPP model is aimed at helping educational planners to make better decisions about their educational programmes and products. Based on the idea that evaluative information is an essential component of good decision-making, the management oriented approach adopted in CIPP strives to provide

pertinent information for those requiring legitimate, unbiased evaluative information in order to reach a compelling judgment concerning the current state of a psychomotor programme [10]. This approach emphasized the need to meet the informational requirements of those in managerial positions who are responsible for the implementation of the programme [9]. Focusing on these value-oriented approaches, Stufflebeam [9] further defined operational evaluation for this model as a process of delineating, obtaining, reporting and applying descriptive and judgmental information about the merit, worth, probity and significance of an object. He noted that an effective evaluation requires identifying and continually guiding a decision, providing accountability information and advocating effective programme methodologies. The CIPP model for instance, considered the study objectives which spelt out what polytechnic education in Nigeria was established to achieve of which is primarily the production of skilled manpower for the nation's industrial advancement.

The context evaluation in CIPP evaluates to ascertain if the engineering programmes of polytechnics in Nigeria meet their main objectives in terms of the training given to engineering technology students to acquire relevant work skills which are demanded in the industries for the technological advancement and industrial development of the nation.

The input in CIPP model referred to the polytechnic resources required to run effective polytechnic education in Nigeria (that is, how adequate and available are these polytechnic education resources for the smooth operation of the system). In a nutshell, this talked about the teaching staff (lecturers and technical staff); the administrative staff, the messengers, typists, computer operators, secretaries, among others.

The process in CIPP model is concerned with how efficient is the utilization of these polytechnic resources to achieve the stated objectives. That is, the process considers how the management of the polytechnics in hierarchical order is able to utilize the available human and material resources for the achievement of the overall objectives of polytechnic engineering programmes in Nigeria.

The product in CIPP model described the quality (worth) of the end products (graduates) of Nigerian polytechnics upon graduation. Often times, product evaluation is ascertained as soon as the polytechnic engineering graduates started working in the industries after their polytechnic education.

Stufflebeam designed the CIPP evaluation model to address four different classes of decision making which are planning (specific objectives), structuring (designing a project around specific objectives), implementing (operating and executing a project), and recycling (judgment and feedback). All these directly correlate with the evaluation methods of this model. An operational knowledge of the four evaluative methods in CIPP model categorically stated what each evaluation method or procedure entails. Although each method was designed to address specific aspects of programme evaluation particularly important to decision-makers, this model is neither linear nor systematic [10]. However, this model can be modified to cater for specific information required by those in decision-making positions [9]. CIPP model is very popular especially in the evaluation of educational objectives in the psychomotor domain (skill areas). The model provides a means for assessing programmes and identifying lacking areas for improvement.

## 1.1. Context Evaluation

In CIPP Model, the objectives of context evaluation are to identify initial information concerning how the programme will function [10]. However, context evaluation goes beyond context definition to incorporate identification of the audience and its needs as well as comparing the programmes intents with the stakeholders' requirements [9]. This method of evaluation employs variety of techniques such as surveys with stakeholders and project participants, system analyses, review of documents and archived data, implementation of diagnostic tests and multiple interviews. The overall purpose of this type of evaluation is to ensure that there is a general consensus of the settings, goals and objectives associated with the evaluation. Context evaluation is aimed at providing a rationale for the determination of educational objective [11]. Context evaluation evaluates whether the objectives of the study are achieved or not.

## 1.2. Input Evaluation

Input evaluation is carried out to put in place support systems, solution strategies and procedural designs for the implementation of the polytechnic education programmes in engineering and technology in order for core objectives to be realized [10].[11] submits that input evaluation provides information on how to employ resources to achieve objectives. [9] opined that for input evaluation to be properly done there is need to ascertain the state of the available resources including personnel and accessible materials (physical resources). Thus input evaluation in the context of CIPP model sought for the resources available for effective technology education in Nigerian polytechnics.

## 1.3. Process Evaluation

Process evaluation according to [11] is required once the instructional programme is operational. Process evaluation considered the allocation and utilization of available polytechnic resources in order for the stated objectives to be achieved. The purpose of process evaluation is to identify the defects in the operational procedures in relation to the design of the programme. Process evaluation is aimed at implementing and refining the programme's design and working procedures. It addresses information about how adequate is the implementation of the programme and further helps to identify the conflicting obstacles towards the success of the polytechnic programmes in electrical/electronics, mechanical, civil, chemical and computer engineering and technology.

## 1.4. Product Evaluation

Product evaluation which is the last constituent in the CIPP evaluation model refers to the ultimate decision associated with the fate of the programme [10]. This decision determines the continuation, termination, modification or refocusing of the programme under review by appropriate bodies [9]. In this context, the National Board for Technical Education (NBTE) has the capacity to decide on the worth of the engineering programmes of polytechnics in Nigeria. The result is a product of collections of descriptions and many archived judgments about the objectives, merits and worth of the programme. Thus, [11] viewed product evaluation as an attempt to measure and interpret the attainments yielded by the programme not only on its conclusion but as often as possible during the operation of the programme. Thus, formative and summative evaluations are very necessary in carrying out product evaluation. However, for decision-makers to reach logical conclusion, the evaluator must collect both quantitative and qualitative information from all personnel and stakeholders concerned (i.e. lecturers, students, industry based supervisors, polytechnic administrators and parents). Sometimes, product evaluation can be categorized into impact, effectiveness, sustainability and transportability sub-categories as the need arises so as to obtain more accurate information about the long-term effects of the programmes. Consequently, product evaluation helps to determine the suitability of the graduates for effective engagement in the world of work based on the training received in engineering and technology fields with the available educational resources in Nigerian polytechnics.

## 2. Outcome-Based Evaluation Model

Outcome-based evaluation (OBE) model comprised four types of evaluation commonly used in assessing learning outcomes in technical vocational education and training (TVET) programmes of Nigerian polytechnics. These evaluation types are programme evaluation, effectiveness evaluation, impact evaluation and policy evaluation. According to [12], programme evaluation is the type of evaluation that uses either individual-referenced or organization-referenced outcomes to determine whether the programme is meeting desired outcomes and uses or not. Effective evaluation on the other hand reports the extent to which a programme is meeting its goals and objectives; impact evaluation studies whether or not a programme has made a remarkable difference (impact) on students as adjudged by stakeholders compared to an alternative programme; finally, policy evaluation researches the equity, efficiency or effectiveness of policy outcomes for programme improvement. These sub-categories of Outcome-based evaluation are briefly described as follows:

### 2.1. Programme Evaluation

This typically seeks to determine the outcome (impact) of the program on recipients (trainees). Again, these evaluations are used most often in education, health and social services domains all of which demand feedback on the worth of the program on recipients. The expected results may vary but often include increased knowledge, behavior modification, learned skills and changes in condition of the recipients. Program outcomes are measured to ensure its effectiveness in technical education. The outcome must be determined to ensure consumers' appraisal in terms of satisfaction and functionality; in terms of adaptive behaviors and role status. Again, personal appraisal is appreciated in which experiences are considered. However, for successful program evaluation, there is need for a change and accountability in strategic plans and goals performance with a developed monitoring mechanism to ensure adequate compliance [13]. Outcomes must be measured wisely owing to the practicality of the management (decision-makers) in addressing the needs of the program. It should also be noted that programme evaluation outcomes sometimes are affected by economic, demographic and other related factors.

### 2.2. Effectiveness Evaluation

Effectiveness evaluation seeks to determine whether the goals and objectives of the programme are met. This is done by comparing the programme's goals with its achieved outcomes; reporting the programme's performance and value outcome and the provision of formative feedback for programme improvement [12]. Outcome-based evaluation model emphasizes on the five effective analyses steps: Performance goal, purpose and comparison condition, methodology,

data collection and analyses and individual and organizational-referenced outcomes. An effective evaluation requires organizational definition of its strategic performance plans. Consequent upon the gathered information is the programme's results specified. Adopting outcome-based evaluation model entails that the evaluator should systematically apply effectiveness evaluation using the available data in order to arrive at useful recommendations for programme improvement [13]. This evaluation process aids policy makers' responses and conclusions on crucial issues such as programme's objectives and outcomes and maintenance of resource values. In an attempt to implement effectiveness evaluation, evaluators faced some challenges which include: development of policy, objectives and terms of reference, establishment of monitoring framework, allocation of resources, management, analysis and interpretation of data and presentation of results, establishment of cooperative, long-term commitments between cooperative organizations and other stakeholders as well as recommending styles of management within the organization emphasizing prescriptive approaches and standardized rules to monitoring results as well as taking appropriate actions.

## 2.3. Impact Evaluation

Impact evaluation strives to determine whether the programme is better than other related programmes. Impact evaluation focuses on the impact of the programme and finds out whether those impacts can be attributed to the intervention being employed or the services rendered. It also gives feedback to stakeholders in the areas of accountability and improved programme plans [12]. Carrying out impact evaluation also requires a comparison group with which results and outcomes could be compared. In impact evaluation, the evaluator must consider the people served by each programme, services rendered and results and then determine whether any statistical significant difference exists in the results. The result leads to an impact statement based on the significant mean difference. Finally, there is need for the evaluator to discuss the main results and their main implications to the programme. According to [14], the programme evaluator can decide whether to apply the suggested recommendations for policy improvements. As a type of outcome-based evaluation, an impact evaluation results may appear to be less applicable for continuous improvements. In essence, impact evaluation provides for outcome-based policy evaluation.

## 2.4. Policy Evaluation

Policy evaluation is all about determining the workability of a given policy. It determines outcomes in relation to the programme equity, efficiency and effectiveness. Policy analysis usually focuses on performance values as applicable in other types of evaluation in outcome-based evaluation [12]. Current education, healthcare and social services programmes are often studied and evaluated to ascertain their efficiency and effectiveness [15]; [16]; [17]. The essence of policy evaluation in Nigerian polytechnics is to bring about improvement and accountability in the programmes. This type of evaluation considers the individual, the programme and the system generally. In policy evaluation, the policy intents, contents and goals must first be identified, followed by the identification of the core values of the policy. Thereafter, the intended outcomes must be analyzed in line with the stated goals. Policy evaluation deals with subjective matters and must rely on evaluators to interpret data. Basically, policies are intended to generate outcomes and also help stakeholders to report those outcomes in various perspectives. Policy makers consider outcomes such as rate of graduation, students' test scores, teachers' proficiency, accreditation, parent involvement, school environment, students' satisfaction, academic skills, social adjustment, social belonging, graduates' employability and empowerment [18]; [19]; [17]; [20].

## 3. Kirkpatrick's Evaluation Model

The Kirkpatrick's evaluation model has been the model most widely recognized and used for evaluating training programmes. The model asserts that training programme effectiveness can be evaluated by looking at four levels: Reaction (how participants in training react to the training), learning (the extent to which participants changed their attitudes, increased knowledge and/or skill), behavior (the extent to which participants' behaviours are transformed), and results (the final results of the training). Kirkpatrick's model has been adopted for a long time owing to its simplicity, practicability, effectiveness, flexibility and completeness. According to [21], the strength of the model lies in its simplicity and its ability to help people think about training using appropriate evaluation criteria. It further provides vocabulary and taxonomy for the criteria used. It is widely used in various contexts such as the Navy, academics [22], and communication technologies [23], educational simulations [24] amongst others. According to [22], measures like students' number, recruitment date and students' retention in higher education are very crucial where Kirkpatrick's model is applied. However, they stressed that some academic programmes evaluation rely on the presentation of more programme-related data from a variety of sources. In an academic setting, this evaluation model is very useful as it measures factors such as students' satisfaction, learning proficiency, skills acquisition and overall programme effectiveness [22]. The applications of Kirkpatrick's model are discussed under the following sub-headings:

## 3.1. Assessing Response of Learners

This involves the determination of the feelings of the learners towards the programme. It detects whether the learners liked the programme or not and whether it was attitudinal (affective) rather than behavioural [21]. In the same vein, [22] opined that reaction refers to the trainees like or dislike of a programme. The aim of using this model is to receive feedback that will contribute immensely to stakeholders' decision-making. Data gathered from trainees show their reactions to the instructor, the course, and the learning environment, and these reactions are evaluated using appropriate statistical tools. Responses may be in the area of the course, style of presentation, content and quality of training materials. Key evaluation techniques adopted are asking, listening, and using evaluation forms at the conclusion of a course. Some evaluation questionnaires used in the reaction level have been called happiness sheets or smile sheets as they measure how good students prefer the training. However, reaction level questionnaires can reveal valuable data if more complex questions are asked. Questions about the relevance of the objectives, course ability to maintain the interests of the participants, amount and appropriateness of interactive exercises, ease of navigation, perceived value, and transferability to the workplace could all be submitted.

## 3.2. Measuring Learning due to Training

In assessing learning due to training, the extent to which the learners experience changes in attitudes, skills or motivation as a result of the training received are critically assessed [25]. These noted changes could be in the cognitive (knowledge and factual information), psychomotor domain (skills) and affective domain (attitudes). The cognitive test is issued majorly with an open-ended multiple choice tests to ascertain the amount of information retained. Psychomotor domain measures the performance of the learners in skills acquisition within the training environment, rather than the actual work environment. The affective domain focuses on how the learners feel or think about the content of the training, the motivation to use training skills, and confidence in the usage of skills acquired, on the ability to reach their goals, on the interpretation of information, facts and principles and the techniques adopted and the degree to which the learners have actually learnt [21]; [26], [25]; [22]; [27]. Common measurement tools for measuring learning via training are interviews, surveys, tests, case studies and quizzes. In schools, the measurement is done with examinations, quizzes, mid-terms, projects and/or portfolio assessment common in educational settings [22].

## 3.3. Assessing Changes in Learners' Behaviours

Behaviour is the degree to which learners transfer attitudes, knowledge and skills taught in one class to subsequent classes and non-academic settings such as the work environment [24]. A change in behavior requires an inner desire to change. Here, changes in the behaviour of the learners are as a result of the acquired training measured in the world of work. Furthermore, encouragement, help and rewards might also be required. According to [28] performance on the job can be improved via appraisal and coaching. Again, the ability of the learners to transfer the learned skills, knowledge and attitude to real work situations is evaluated. In other words, the achievement of performance objectives is determined using learned principles and techniques on the job [21]. The evaluation of behavior assesses learners' ability to carry out tasks more effectively after the training course, provide better care to clients and be more knowledgeable or skillful in job performance [26]. Here, it is very crucial to collect data to verify the degree at which learners applied the knowledge acquired from a training course on their jobs. The transfer that occurred in their behaviour can be attributed to their performance. Many trainers try to find out if the knowledge, skills and attitude acquired from training are adequately applied in the learners' job environment for increased performance. The trainers view this as the truest assessment of a training programme's effectiveness.

## 3.4. Determining Results of Training

This is the most difficult and capital-intensive step in this model. It focuses on how training alters organizational functions such as grievances, turnover, costs reduction and absenteeism [29]. The measurement of results from training assesses the bottom line and the final results but only 3% of training evaluations occur at this level [26]. The definition of results depends on training programme goals. Goals might include desired end results, reduction of costs and turnover, reduction of absenteeism and grievances, increase in the quality and quantity of production or improving morale [21]. In a situation where there are no well-defined results, a good academic programme may be scrapped because of lack of sufficient data to attest to its accomplishments and benefits to the many stakeholders involved [22]. Organization needs some evidence if not outright proof of achievement at this level. Results measure the degree to which the output of the learners' workgroup or organization has improved due to the learning programme [27]. The result level is the most difficult level of the model to be evaluated [25]. It is advisable that management decides which results are relevant to decision-making process and evaluation. Measuring the impacts of the training programme on the organization could include cost versus benefit, proof versus evidence on report productivity, customers satisfaction, efficiency, morale and profitability [25].

## 4. Conclusion

Programme evaluation is geared towards improving the worth of any educational programme for maximum efficiency and productivity. Therefore, having full knowledge of relevant theoretical models applicable to polytechnic engineering technology programmes in Nigeria will not only help educational administrators to improve the quality of engineering technology programmes in Nigerian polytechnics but will also ensure that the right skills are acquired by students in line with the needs of the local industry thereby boosting the proficiency of skilled and semi-skilled technical manpower needed for increased productivity in local industries. Consequently, for Nigeria to attain technological advancement and economic transformation, engineering and technology education in Nigerian polytechnics need to be revamped in line with global best practices so as to meet industrial expectations. Polytechnic engineering technology curricula need periodic review to accommodate emerging trends in technological innovations as obtainable in developed economies as this will eliminate the skill mismatch between the skills acquired by engineering graduates of polytechnics and those actually needed for productive work in the industries; which is a valiant prospect for economic and technological advancement of the nation.

*Recommendations*

- Government should ensure mandatory application of theoretical models in evaluating all engineering programmes by lecturers and technologists in Nigerian polytechnics.
- Government through the National Board for Technical Education (NBTE) should ensure compulsory internship programme for all polytechnic engineering students to enable them acquire relevant skills in line with the needs of the industry.
- Supervised project-based learning should be part of the evaluation processes of engineering technology programmes in Nigerian polytechnics.
- Engineering lecturers in polytechnics should be encouraged to use more of student-centred instructional strategies in the training of students to guarantee their effectiveness in the world of work upon graduation.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest.

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