ABET Engineering Technology Criteria and Competency Based Engineering Education

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Abstract - **The universities in different countries follow their own curriculum development philosophies with the intention of producing "work-ready" engineers. "ABET Engineering Technology Criteria" was introduced to rationalise the various curriculum development philosophies followed by different universities in the USA. This paper highlights the researches done for the creation of competency related to engineering technology programmes being offered in India, which can also help in the development of the competency-based curriculum. This is being done with an attempt to usher in some level of rationalisation of Indian technical education system. On comparing the competency bank experience with ABET criteria, the author is of the view that the some of its concepts could be useful to enrich "ABET Engineering Technology Programmes Criterion # 2 'a to k' and Criterion # 8. Related to these concpts, two major classifications of industries which also influence the competencies to be identified and developed in the under-graduates of the engineering education institutions are also discussed.**

Index Terms – ABET Engineering Technology Criteria, competency bank, occupation-specific competencies, Manufacturing Marketing and Servicing (MMS), Research & Development (R&D).

1.0 INTRODUCTION

The digital revolution and other technological advancements have initiated the 'changing nature of work' at the work place quite rapidly [13]. Such changing trends in the industry requires periodic review of the curricula of various engineering technology programmes of the respective occupations for identifying new/changed competencies that arise and thence to remove the obsolete ones to make room for the new. Here, the term "industry" means any enterprise (wage employed or self employed) where a graduate can undertake to earn a living.

This periodic review necessitates the need for a specialised organisations like the ABET in the USA and National Institute of Technical Teachers' Training and Research (NITTTR) Bhopal, India. NITTTR Bhopal, is one of the four premier organisations established by the government of India for the development of the technical/engineering education systems in the country. It endeavours to respond to the continual 'changing nature of work' [13] by conducting researches in the area of technical/engineering education and suggest improvements in the engineering education programmes to fulfill the changing needs of the industry. One such initiative for the creation of competency banks by NITTTR Bhopal is discussed here, if at all, to enrich the body of knowledge of engineering education with the work being done by such leading organisations like ABET in the USA and others, for the benefit of the world of engineering (technology) education.

Most of the universities in different countries use their own philosophies in offering engineering education programmes to produce engineering technology graduates needed by the industry. Considerable amount of research is taking place regarding the way engineering technology programmes are to be designed, offered and implemented. ABET has rightly recognized this predicament by introducing the "ABET Engineering Technology Criteria" [9] to rationalize the various philosophies followed by different universities in the USA. This is indeed quite a commendable step to produce competent graduates.

However, the author believes that "ABET Engineering Technology Programmes Criteria # 2 'a to k' and Criterion # 8" [11] could be enriched further by creating "competency banks" consisting of "occupation specific" competencies [12]. This could help to trigger meaningful curricular modifications like the competency-based curricula to render them more "explicit" than "generic" and thereby help the engineering education institutions to produce "work-ready" graduates with greater degree of employability for the industry. This move could initiate considerable amount of debate and therefore the need for more research in this direction. The author has already initiated such researches in this direction with respect to engineering technology programmes in the Indian context. But, first a brief background of the Indian engineering education system may help in this discussion.

2.0 GRADUATE ENGINEERING AND ENGINEERING TECHNOLOGY PROGRAMMES IN INDIA

Currently in India, there are about 1400 engineering education institutions offering engineering technology programmes and affiliated to several universities spread across the country. The programmes offered by government engineering education institutions continue to be highly subsidised and funded by the government. Of late, however a large number of self-financed engineering education institutions offering various engineering technology programmes have come up in several parts of the country. All these institutions are monitored by the government body AICTE (All India Council for Technical Education).

Excepting the IITs (which prepare the undergraduate students primarily for R&D work), by and large the syllabii/curricula of the engineering technology programmes, with respect to each occupation, offered by rest of the universities and engineering education institutions in the country are almost the same i.e. they are focused to prepare the undergraduate students for R&D work and not engineering technology jobs. But the names of the engineering technology degrees awarded by the universities and engineering institutions do not bear great relevance to the curriculum design philosophy. They go by different names viz. "Bachelor of Engineering (BE)", "Bachelor of Technology (B.Tech.)", "Bachelor of Science Engineering (B.Sc.Engg.), rendering it difficult for several stakeholders to understand their similarities and differences. To address this scenario and with an attempt to bring in some level of rationalisation, the "competency bank" research was undertaken by the NITTTR Bhopal in which the author was the team leader. The outcomes of this research is analysed with respect to ABET Engineering Technology Criteria.

3.0 ABET ENGINEERING TECHNOLOGY CRITERIA

It is known that ABET [9] has broadly classified the accreditation criteria of *engineering technology programmes* being offered by the schools of engineering into two broad categories:

- *General Criteria for Basic Level Programmes*
- General Criteria for Advanced Level Programmes

However, the discussion in this paper is with respect to the first one i.e. *'General Criteria for Basic Level Programmes'* for *engineering technology programmes* is considered here.

- Criterion 1. Programme Educational Objectives
- ***Criterion 2 Programme Outcomes***
- Criterion 3. Assessment and Evaluation
- Criterion 4. Programme Characteristics
- Criterion 5. Faculty
- Criterion 6. Facilities
- Criterion 7. Institutional and External Support
- ***Criterion 8. Programme Criteria.***

Of these only criterion # 2 and criterion # 8 are considered here.

3.1 ABET Engineering Technology Programme Criterion # 2

ABET Engineering Technology Criterion #2 [11] "a to k" i.e. "Program Outcomes" states that:

An engineering technology programme must demonstrate that graduates have:

a) an appropriate mastery of the knowledge, techniques, skills and modern tools of their discipline
b) an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology
c) an ability to conduct, analyse and interpret experiments and apply experimental results to improve processes
d) an ability to creativity to design systems, components and processes appropriate to programme objectives
e) an ability to function effectively on teams
f) an ability to identify, analyse and solve technical problems
g) an ability to communicate effectively
h) a recognition of the need for, and an ability to engage in lifelong learning
i) an ability to understand professional, ethical and social responsibilities
j) a respect for diversity and a knowledge of contemporary professional, societal and global issues, and
k) a commitment to quality, timeliness, and continuous improvement.

3.2 ABET Engineering Technology Programme Criterion # 8

The other *Criterion # 8* i.e. Programme Criteria [11], also considered here states that: "Where applicable, each programme must satisfy programme criteria that simplify these general criteria and provide the specifics needed for a given discipline. A programme must satisfy all programme criteria applicable to the technical specialties implied in the programme title".

3.3 Observations of ABET Criteria vis-à-vis Competency-Based Engineering Education

At the *macro level, Criterion #2* and *Criterion # 8* appears to help in the rationalisation process of the engineering technology programmes being offered. But, on closer scrutiny it is seen that each statement of "a to k" and the statements in criteria # 8 [11] with respect to each discipline continues to be more or less *"generic"* than *"occupation specific"* vis-à-vis "competency bank" [12] (the details which is beyond the scope of this paper, but could be presented at the conference). Therefore, curriculum rationalisation for the same occupation may become difficult, as there can be more chances of different types of curricula by developed by different institutions leading to difficulties in curricular decision making for the stakeholders.

The greater explicitness of the statements in the competency bank can intrinsically lead to the development of *competency-based curricula* by the different schools/colleges of engineering, thereby enhancing the rationalisation of the curricula of each occupation. The *course names* to be offered emerge out from many of the competency statements. *Transfer of credits* also become easier when students change/leave universities midway to continue their studies later or join some other university. Further, these explicit statements tend to prepare under-graduates to develop the requisite occupation specific competencies to be "work ready" for immediate employment on graduation. Moreover, these *threshold* competency statements to be possessed by the engineering technology graduates at the *entry-level* are better understood by the Indian industry. This discussion will become more clearer on examining the *major functions of the industry* from a broader perspective.

4.0 TWO MAJOR TYPES/FUNCTIONS OF INDUSTRY

Depending on the products of manufacture or the services the industries provide, all the industry functions and the sub-functions that they do, all industries fall in two broad categories:

a) *Manufacturing, Marketing and Servicing (MMS) type of industries*

b) *Research & Development (R&D) type of industries*

The graduate engineering technology programmes are generally expected to produce graduates to work in the first type of industry i.e. MMS; while the graduate engineering programmes are expected to produce graduates for the second type of industry i.e. R&D. Some industries may perform both the above functions, but such industries are very few in India.

This classification separates out the competencies and hence the curriculum designs required for engineering and engineering technology programmes. This calls for occupation specific statements and competency banks related to each discipline for better understanding to all stakeholders [12].

4.1 Manufacturing, Marketing and Servicing (MMS) Type of Industries

85% of the industries in India are of the "MMS*"* type (and the author believes that this may hold true for the USA too and if not far off from the mark, it may hold good for the rest of the world as well). But, it is observed that more than ninety percent of the schools/colleges of engineering India (again which may be true elsewhere in the world as well), have their curriculum designs tuned to fulfill the second major function of the industry i.e. *Research & Development (R&D) jobs.*

However, the interesting fact is that when the students get enrolled in the schools/colleges of engineering in India, most of them expect to get immediate employment on graduation. It is only when the *"MMS"* type industries (who are the majority employers in India) reject the graduates during recruitment and leaving them unemployed, do they realize that their curriculum was not *explicitly* engineering technology focused. These industries say that they do not possess the occupation specific competencies needed by them, leading to high levels of unemployment.

Even if a few of the industries do hire some of these graduates, though they are not *'work-ready',* the industries put them to rigorous in-house training at the industry expense for 12 to 24 months to develop in them the needed *occupation specific* competencies. Only on the attainment of these competencies are they retained in the industry and given the actual jobs. This requires the industry to incur considerable amount of additional expenditure and wastage of time, which should have been done by the schools/colleges of engineering.

This scenario has lead to massive unemployment and/or under-employment (i.e. they work not as engineers, but as foremen or other jobs) of the engineering technology graduates in India. As they are not fit for the *MMS jobs* and *R&D jobs* are rare, they become unemployed, so they switch over to do some other work which are not at all related to engineering for which they have been trained in the engineering education institutions, thereby leading to colossal waste of the taxpayers' money (as engineering education continues to be highly subsidised in India).

4.2 Research & Development (R&D) Type of Industries

Generally, in most of the countries, as in India there are relatively very few industries (say about 15%) performing this second major function of R&D viz. Indian Space Research Organisation (ISRO), Defence Research Development Organisation (DRDO) and few others. However, they employ relatively very few engineering graduates every year.

5.0 TWO CATEGORIES OF ENGINEERING EDUCATION INSTITUTIONS

The above two major groupings of the industries classifies the engineering education institutions also into two categories.

- The ***first*** category of engineering education institutions which are relatively more in India, need to design and implement competency-based curricula to produce *"engineering technology graduates"* possessing those competencies needed by the "*MMS"* type of industries which are substantially more in India (compared to R&D related industries). This situation may be true in several other countries as well.
- The ***second*** category of engineering education institutions should design their curricula to produce *"engineering graduates"* to take up "*R&D"* related jobs. Some institutes such as the IITs, which are relatively few in India, *primarily* produce graduates to perform R&D work. IITs are 'chartered' to produce graduates to work in the 'cutting edge' of engineering technology.

Therefore, the more occupation specific and competency-based the curriculum is, the better it is understood by all stakeholders without any ambiguity.

6.0 CURRICULUM DESIGN AND RELATED JOB OPTIONS

Table-1 endeavours to summarise the discussions thus far to correlate with the curriculum design, job opportunities and ABET Criteria.

TABLE –1
ABET ACCREDITATION CRITERIA & CURRICULUM DESIGN

***ABET Engineering Technology Programmes Criteria # 2 & 8 and Curriculum Design* (1)**	**Type & number of industries in India (2)**	**Job opportunities for Engineering Technology graduates in India (3)**	***Curriculum Design of Engineering Technology programmes in India* (4)**
Curriculum Design of Engineering Technology Programmes may be enriched to fulfill the needs of MMS industries by adapting competency based curriculum aspects	85% MMS industries	about 85%	• *Competency bank and based-curriculum to enhance employability in MMS industries* • *Currently more R&D focus in curriculum*
	15% R&D jobs	about 15%	*Curriculum Design of engineering programmes have R&D focus*

On observing the Table-1, it can be concluded that columns 1 and 4 can be controlled by the engineering education system. Whereas columns 2 and 3 are industry dependent, which is a pointer that the curriculum design needs to be more explicit and relevant to the changing employment patterns of the industry, so that the graduates can be forthright put on the job from the first day of their employment in the industry.

Such a scenario could be true in the USA (and other countries) also, which therefore becomes necessary for industry vetted occupation specific competencies to be identified and "banked". If *occupation specific competencies* are adapted in ABET Engineering Criteria # 2 & Criteria # 8 [11], the chances of ushering in uniformity in the curricula of engineering technology programmes for various occupations in different institutions becomes stronger – for the very cause for which the ABET Engineering Criteria was introduced.

Therefore, to render the engineering technology graduates more employable, there seems to be a strong need to identify occupation-specific competencies [7] to be disseminated to all stakeholders to usher in rationalisation. Such competencies can lead to the development of *"competency-based curriculum"* to produce engineering technology graduates who are "work-ready" and to do the jobs in the industry outright without any long-term training by at the industry premises (and drain their resources again).

7.0 Need of Occupation Specific Competencies

The effectiveness and efficiency of any educational programme is largely dependent on the philosophy of the curriculum design followed. The curriculum is the one that drives the engineering technology programme to its destination. If specific occupations are not focused in the curriculum design philosophy, the products of the engineering technology programmes may not be "work-ready" and therefore not readily accepted by the industry. Therefore, to reduce the unemployment and 'under employment' levels, it

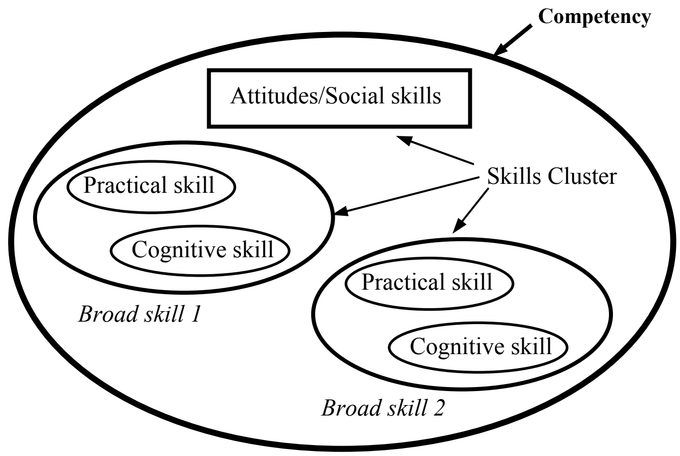

FIGURE -1
Concept of a Competency

becomes necessary to consider 'occupation-specific competencies' in the curriculum designs.

Since different persons understand the term 'competency' differently, the author in his research [4,5,6] defined the term competency to bring in more clarity for all concerned, especially with reference to engineering and technical education. It states that '*the competency is* a *statement which describes the integrated demonstration of a cluster of related knowledge, skills and attitudes that are observable and measurable, necessary to perform a job independently at a prescribed proficiency level'* [5,6].

This definition is illustrated in Figure 1 as a complete system comprising of several broad skills and sub-skills (like the practical skills, cognitive skills and social skills and/or attitudes required in performing a given job/task. This definition means:

- that the competency is an overt and measurable performance in terms of quantity, quality, time, cost or a combination of any of these, for which `action' or `performance' oriented verbs are to be used in writing competency statements.
- a cluster of broad skills consisting of cognitive(intellectual) skills, practical skills and social skills/attitudes, skillfully weaved together into an integrated whole.
- the skills also involves higher order cognitive skills of Bloom's taxonomy [2] required to analyse, interpret, design, evaluate, create, plan, troubleshoot, diagnose etc. as well as lower level practical skills of Dave's taxonomy [3] such as cut, join, machine, measure, solder, paint etc.
- a 'job' is an activity, which has a definite beginning and ending point, that can be performed over a short period of time, independent of other work and which results in a product, service or decision.
- 'perform' a job at a specified proficiency, means performing a given job successfully every time he/she is asked to do. In other words, tending towards more

'reliability' and 'validity'. The 'proficiency level' here is the 'threshold level' [8] i.e. at the entry level to the industry after 4 years of study in the schools/colleges of engineering.

For the industry, the competency logically precipitates out in terms of *cluster of broad skills* as shown in Figure-1 for each job to be performed. On the other hand, the curriculum developer/teacher thinks still further in terms of practical skills, cognitive skills and social skills/attitudes within each broad skill, as they are the basic building blocks that make up a competency. In fact, they are to be individually developed in the students and an integrated behaviour is expected in the students. However, it is understood by the industry due to the time constraint of 4-year degree programme being offered by the university, only *threshold competencies* [4], as against *experienced worker competencies* (EWC), are expected in the student. On the basis of this definition, the author has been conducting researches and one such research on competency bank is discussed here.

8.0 COMPETENCY-BASED EDUCATION EXPERIMENT

Due to the proliferation of a large number of universities and engineering institutions in India, there hardly existed any common rationale/philosophy for developing the curricula for the various programmes being offered by the schools/colleges of engineering in India. Therefore, to rationalize the engineering education system and to bring in some degree of uniformity in curriculum design philosophies, thereby endeavouring to simplify accreditation of prior learning (APL) and also transfer of credits Competency-based Education (CBE) Experiment was conducted. The NITTTR, Bhopal team under the leadership of the author through this research created an occupation-specific 'competency bank' consisting of industry-vetted competencies. This 'bank' is to serve as a referral point for all stakeholders who are in the business of engineering education like the universities, educational institutions and the industry.

8.1 Terms of Reference

The definition discussed in section 7 helped to benchmark the *occupation-specific* competencies to undertake for the first time in the country a nationally sponsored research to *'identify the competencies required of electrical and electronics engineering degree and diploma holders by the Indian Industry'*. This research was the first step in the creation of a *national level competency bank* in India [7]. This study was initiated considering the engineering technology programmes, as the majority of the engineering education institutions (above 90%) in India were focusing the curriculum design philosophy on producing *'R&D'* engineers, even though the majority employment potential in the industry in India was for *'MMS*' jobs, thus leaving many of the graduates unemployed. In this research, each engineering technology degree or diploma programme was considered as an occupation as each of the programmes were producing graduates for that particular occupation.

8.2 Methodology

In this experiment firstly, the four specific occupations were identified i.e. (a) Degree in Electrical Engineering, (b) Degree in Electronics Engineering, (c) Diploma in Electronics Engineering (d) Diploma in Electronics Engineering. Secondly, this being a research first of its kind, separate research instruments had to be designed [7] for all the four occupations. Pilot-tryouts were conducted, based on which each of the research instruments were modified, finalised, and multiplied. The questionnaires were then sent to various industries in different parts of the country.

During the pilot-tryout of the research instruments, the industry evinced considerable interest, as their training departments could also use these researched lists of competencies. More so, the industry is also benefited, as they also clearly come to know as to what competencies are being developed in the students by the schools of engineering. Moreover, the competency bank will also help in organising their in-house training programmes to develop explicitly specified, researched and benchmarked competencies as by and large, 'life-long learning' has come to be accepted by the corporate world as well.

Several industries from different parts of India responded to these questionnaires. Search conferences were also conducted in two cities of India. Interviews of some employers were also taken for to bring in more reliability and validity to the responses. The analysis of the responses was done; the research report was prepared [7] and submitted to the government of India, who funded this research project. The competency bank that emerged through this research is hosted on the website of NITTTR Bhopal [12] to serve as a referral point for engineering institutions for curriculum development and also for the industry for developing the curricula for their in-house training programmes.

8.3 Outcomes

It emerged from this research [7] that each of the four identified occupations have a set of *generic competencies,* followed by set of "essential competencies", "desirable competencies" and "optional competencies". On examining the 'generic competencies', it can be seen that they are inter-disciplinary in nature, which can help the graduates when working on interdisciplinary teams in the industry. The 'essential competencies' are those without which that particular occupation cannot exist and therefore absolutely essential. The 'desirable competencies' are also part of that occupation but majority of the industries do not require them quite often. The 'optional competencies' are those which are required for highly specialised areas of the same occupation but only by a very few industries.

Just as in commercial banks, these researched competencies based on specific occupations are to be 'drawn out' and/or new or modified ones 'deposited' by the lead organisation (in this case NITTTR Bhopal), which has to maintain the "bank". This calls for research to be an ongoing and continuous activity, so that obsolescence may not creep in, instead the technical/engineering education systems will rise up to meet the occupational demands and the needs of the industry due to ongoing technological advancements.

9.0 COMPARISON OF COMPETENCY BANK & ABET ENGINEERING TECHNOLOGY CRITERIA # 2 & 8

On comparing the competencies in the competency bank [12] it is seen that there are several similarities to that of ABET criteria # 2 & 8. One of the evident similarities is that both focus on specific demonstration of certain competencies.

An example of an occupation specific competency drawn from the *occupation bank* [12] required of an electrical engineering graduate is stated here.

- *Design & estimate the cost of electrical control panels*

On observing this competency it can be seen that, it is similar, but more specific than ABET criteria # 2-"c"*i.e. an ability to conduct, analyse and interpret experiments and experimental results to improve processes,* but more specificity is brought about rendering it *more useful* to curriculum developers and all stakeholders. Whereas a similar statement is not there in ABET criteria # 2, although it is necessary in this case [12].

Another example from electronics engineering is given here.

- *Design and test circuits for optical fiber communication systems* [12]

This is also similar, but more specific than ABET criteria # 2-"f"*i.e an ability to identify, analyse and solve technical problems,* but greater specificity helps the curriculum planners and designers considerably for curriculum development in the universities and the training departments of the industry as well.

A salient feature of these competency bank statements is that the statements more or else spells out the type/name of the courses as well that can be offered to develop these competencies. If specific competencies, as seen in the competency bank [12], are identified for every occupation, then the curriculum development undertaken by different schools/colleges of engineering would be more or less similar leading to a higher degree of rationalisation of the curricula in that particular country.

The author's submission is that the statements in the ABET criteria # 2 is fairly *generic* and therefore there are more possibilities of interpreting them differently by various curriculum development teams of various universities for the same occupation, resulting in myriad types of curricula for the same occupation; thereby taking it further away from curriculum rationalisation process. In so doing, problems related to transfer of credits and accreditation of prior learning, and such other issues are also likely to be more.

10.0 CONCLUSION

Finally, the author's submission is that the ABET Engineering Technology Programme Criteria # 2 "a to k" and criterion # 8 are very good as *generic competencies*, but ABET in the USA and such other bodies in other countries need to identify many more *occupation-specific competencies* and create and maintain *competency-banks* as in this experiment to usher in greater clarity to all stakeholders like the:

- *Curriculum developers* - as to which curriculum design philosophy to adapt during curriculum planning, design, implementation and evaluation
- *Students* - as what competencies to acquire while undertaking the various experiences in the educational institutions
- *Teachers* - as to what and where to develop and assess these competencies
- *Administrators* - as to what resources need to be provided to develop these competencies and
- *Industry* - as to how they can co-operate with the engineering educational institutions in producing "*work-ready"* engineering graduates from the schools/colleges of engineering.

With some further research, this CBE experiment and the "competency bank" concept could also be applicable to ABET Engineering Technology Programme criteria # 2 "a to k" and criterion # 8 as well [10].

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