A research project concerning the development of a scientific model for accreditation and quality assurance in engineering education

Arun S. Patil

Monash University
Melbourne, Australia

ABSTRACT: The accreditation and assessment of higher education, which reflects on the quality assurance, is becoming mandatory for educational providers to produce professional skilled graduates and technologists in workplace activities. An accreditation model with scientific integrity to assess engineering and technology professional competences is an important requirement in engineering education. The literature search shows that various existing accreditation models being implemented worldwide in the assessment of engineering education programmes lack of transparency, scientific integrity and have little or no attention given to the whole cycle of an engineering education system. As such, there is a strong need for an open-ended, well-structured accreditation model to assess engineering courses for quality assurance. The author gives a brief outline of the proposed research project on the design and development of a scientific accreditation model that can be implemented to assess engineering and technology courses. This includes an investigation of important issues of accreditation and assessment processes in engineering and technology courses worldwide. Particular emphasis is placed on the research methodology used in the project where a three-stage assessment of engineering education cycle has been elaborated.

INTRODUCTION

The quality concerns in the higher education sector is not a new concept and has been intensified in the last two decades due to increasing attention given by several countries to reform higher education systems. This can be attributed to several factors, such as the increasing trend of the internationalisation and globalisation of higher and technical education, the increasing number of courses and student enrolments, the expansion of distance and e-learning education, the emergence of a multicultural workplace environment, to name a few [1]. During the past decade, several countries have experienced problems concerning the quality of higher education. The process of the accreditation and assessment of higher education in general, and engineering education in particular, has become a dynamic process in the quality assurance of higher education. It has been observed that designing and formulating a standard and uniform accreditation process is a complex and difficult task.

LITERATURE SURVEY

Globalisation has placed challenges on human lifestyles and economic development all over the world. As pointed out by Badran, human development will be essential to accelerate science and technology for sustainable development [2]. Technology is the key variable in the economic development of any country. Technological progress and economic development are interdependent. The contrast lies in the different standards of living between highly developed nations, such as the USA, and underdeveloped nations, such as Haiti or Zaire. This contrast is a reflection of the levels of different technologies and their effective implementation, as well as the essential services provided by engineers to society [3].

A survey of relevant literature on several economic factors and the status of technical education has led to the formulation of several observations and views, which are also supported by other independent studies. Some of the views are as follows:

- In the USA, 25% of its population has been involved in education in one way or another and the statistics show that the expenditure on education is almost 7.3% of the Gross National Product (GNP); this level of spending has been consistent during the past decade [4].
- The Organisation for Economic Co-operation and Development's (OECD) annual compendium of education statistics shows that the enrolment in tertiary education, including both university-level education and high-level vocational programmes, increased by more than 50% between 1995 and 2002 in the Czech Republic, Greece, Hungary, Iceland, Korea and Poland, and still by more than 20% in Australia, Finland, Ireland, Mexico, Portugal, Spain, Sweden and the United Kingdom [5].
- It has been observed that over the past decade, economic growth was fastest in East Asia and the Pacific region (7.3% a year), as well as South Asia (5.4% a year). This growth was highest in two Asian countries, namely China and India, each accounting for more than 70% of its region's output [6]. However, the incidence of poverty throughout South Asia has changed little over the past decade. Sustained economic growth is critical to reduce poverty in South Asia. This region's Gross Domestic Product (GDP) growth rate reached 5.4% in 1999, making it the fastest growing developing region for the second consecutive year. According to the recent news release by the World Bank, the rapid economic growth in East and South Asia has pulled over 500 million people out of poverty in those two regions alone [7].
- The world income growth is likely to be accompanied by faster growth in world trade and even faster growth in world investment and technology flow. The emergence of East and South East Asia, including China, as the growth

centre of the world, gives an expected rise in the income of this region.

- It has been clearly observed that educational accomplishments are vital to the economic development of individuals and also for the nation. Education is increasingly being considered as an investment for the collective future of societies and countries [8].
- In Australia, the revenues from universities have increased from $5.5 billion in 1991 to $10.4 billion in 2002. The number of students enrolled in higher education system has increased by 30%, that is from 534,500 in 1991 to 695,500 in 2000. Also, overseas student enrolments in Australia in the higher education sector has increased to 188, 277 in 2000, that is by 16% between the academic years 1999 to 2000 [9].

A literature search has revealed strong evidence that the quality of higher education of a country impacts significantly on its economic progress. The lack of quality higher education has clearly influenced the overall progress of developing and underdeveloped nations. As a result, the quality assurance in higher education is becoming not only important, but also mandatory for educational providers in order to produce professional skilled graduates and technologists in workplace activities.

ACCREDITATION AND QUALITY ASSURANCE IN HIGHER EDUCATION

The history of traditions in accreditation and quality assurance is the oldest in the USA [10]. Accreditation, which emerged as a national phenomenon in 1906, began as a relatively simple idea; however, it has since changed in the direction of a complex evaluative tool [11]. Quality assurance was an integral part of professionalism. Until the mid-1980s, any debate on the concern of quality and standards in higher education was mostly internal due to the higher education system [12].

In education, accreditation involves the process of recognition of an educational institution or educational programmes based on standard qualifications and criteria. The accreditation of higher education gives recognition and a guarantee of minimum quality in higher education. This level of education plays an important role in a country's economy by producing a labour force of generic and specialised skills.

The five important stages of development described by Finch in the quality framework in order to improve the level of quality performance in any organisation are as follows:

- Awareness;
- Measurement methods;
- Process focus;
- Alignment of objectives;
- Customer orientation [13].

Due to the increasing trend of the internationalisation of higher education, accreditation has become a dynamic process of quality assurance.

As pointed out by Green, most of the quality assessment proposals used so far in the higher education system are controversial [12]. This is due to several reasons, such as the following:

- The agency/authority carrying out the assessment;
- Criteria used for the assessment;
- The relationship between quality audit and quality assessment in education, etc.

ACCREDITATION IN ENGINEERING AND TECHNOLOGY

The accreditation and quality assurance process in engineering and technology programmes began voluntarily with the help of the Accreditation Board for Engineering and Technology (ABET) in the USA and later in several other nations. Various organisations at the national level are also developing and carrying out the process of accreditation in other countries, including: the Canadian Engineering Accreditation Board, the Hong Kong Institute of Engineers, the Engineering Council of the UK, the National Board of Accreditation, India, the Institute of Engineers, Ireland, Engineers Australia, etc. The two important systems or consortia of the accreditation and quality issues of higher engineering education are the Washington Accord and the Bologna Process.

The Accreditation Board for Engineering and Technology (ABET)

In the USA, several engineering and technology institutions have been reaccredited under the assessment standards of ABET's Engineering Criteria 2000 (EC2000). Also, many other institutions are set to devise and implement assessment models based on the revised assessment standards of the ABET's Criteria for Accrediting Engineering Programmes (effective for evaluations during the 2004-2005 Accreditation Cycle) [14].

The Washington Accord

The Washington Accord is an important multinational agreement signed in 1989 by six nations, incorporating the USA, Australia, Canada, the UK, Ireland and New Zealand [15]. Two other countries, namely Hong Kong and South Africa, joined as signatories of the Accord in 1995 and 1999, respectively. The objectives of the Washington Accord are to recognise the substantial equivalence of accreditation systems of various organisations and engineering education programmes in the signatory countries.

The Bologna Process

The Bologna Declaration of 1999 immediately followed the Sorbonne Declaration of 1998. In the Bologna Process, the 29 ministers of European higher education departments decided to strengthen and promote the European higher education system by the year 2010 [16]. One of the important decisions in the meeting was the adoption of a binary system of higher education in Europe, ie the system based on two cycles, such as undergraduate and graduate. This is of utmost importance in the process of the internationalisation of higher education, which helps in the promotion of student mobility within Europe, as well as globally.

LABORATORY ACCREDITATION

Engineering students need to be prepared for the increasing use of advanced and appropriate technology in their future workplaces. Recent studies in engineering education suggest that laboratory work can positively influence students' learning skills and can also help in understanding important concepts in the course [17]. Laboratory procedures are essential learning tools in engineering and technology education that can be used to enhance experimental instruction in engineering courses. The integration of laboratory procedures differentiates engineering courses from other disciplines. As a result, laboratory accreditation is a very important and essential factor in the quality of engineering education.

THE NEED FOR ACCREDITATION PROCESSES

Accreditation and assessment is very important in order to maintain the quality of engineering education in any nation, which, in turn, can directly affect the status and quality of engineering graduates, and hence the technical workforce. For instance, with the successful implementation of the so-called *Capability Model* as a new approach in the Total Quality Management (TQM) system in Bergen University College, Bergen, Norway, student and teacher productivity has increased by 10-20% within one year. Also, the new tool was very much useful for the quality improvement in educating students, as well as to implement a quality culture within the institution [18].

The benefits of the educational assessment and accreditation process for engineering and technology can be divided into two parts, namely academic (student) and administrative (institutional).

The academic benefits for students may be listed as follows:

- Design and implement advanced curricula, courses and laboratory works;
- Measure learning outcomes of students and identify strengths and weaknesses;
- Foster industrial interactions and the placement of students;
- Identify and develop the professional developments of students;
- Design quality educational programmes in engineering and technology, etc.

The administrative benefits for institutions can include the following:

- Improve classroom and laboratory facilities;
- Develop and implement faculty resources;
- Identify reliable communication tools and facilities;
- Identify and attract funding resources and agencies;
- Strengthen national and international networking, etc.

METHODS OF ACCREDITATION AND ASSESSMENT

In order to assure the quality of engineering education, various factors can be analysed and assessed in an engineering institution. It has been found that several efforts have been made to devise and develop assessment programmes for the accreditation of engineering courses [19][20]. However, most of these developments focus on the accreditation requirements of the ABET for engineering programmes in the USA and the Bologna Declaration in the European Union (EU).

The most common actions of the accreditation models include the following key elements:

1. Self-assessment of an institution;
2. Peer review and visits;
3. Evaluation and reports.

The guidelines given in the ABET Accreditation Policy and Procedure Manual also recommend that these three steps be carried out for an evaluation during the 2004-2005 accreditation cycle [21]. These guidelines seem to be predominantly outcome-oriented.

HYPOTHESIS AND RESEARCH OBJECTIVES

A literature search on the accreditation and assessment of higher education shows that there is no common agreement or criteria that can be used in the accreditation and assessment of engineering education. A survey of literature and relevant observations made indicate that various assessment models have been developed regionally, as well as internationally, in order to accredit engineering courses. However, they lack the standard scientific requirements of the accreditation process.

The research hypotheses derived in this project can be summarised as follows:

- Most of the existing accreditation models are non-uniform, too complex, non-transparent and do not fulfil all the scientific requirements of an accreditation and assessment process in engineering education.
- The existing accreditation models concentrate mostly on one component of the educational system, with little or no attention being given to the whole of the cycle in the engineering education system.
- There is a strong need for open-ended, well-structured assessment programmes to accredit engineering courses.

The main objectives of this research project can be defined as:

- To investigate important issues of accreditation and assessment process in engineering and technology courses worldwide.
- To design and develop a uniform, transparent and scientific accreditation model for engineering courses that will comprise of all three parts of the educational cycle, namely the *Input*, the *Process* and the *Output* (please refer to Figure 1 on page 14).
- To design and develop a scientific methodology for the standard professional profile of engineering graduates.

RESEARCH METHODOLOGY

The research methodology will consist of the following:

- Comprehensive literature review;
- Internet search;
- Review and investigation of existing accreditation systems worldwide;
- Testing of the hypothesis;
- Investigation of important issues of accreditation for engineering courses;
- Design and development of a scientific model of accreditation;
- Evaluation of the accreditation model, review and corrections;
- Discussions and recommendations.

LITERATURE REVIEW

A comprehensive literature survey of accreditation process in higher education in general, and engineering education in particular, will be carried out. A literature search will also be carried out on various existing accreditation methods in order to investigate the need for an appropriate and efficient scientific model. This may include a thorough literature review of the following topics:

- Review existing literature and research on various accreditation and assessment models in engineering education, and the weaknesses and strengths of these models.
- Review of literature, exploring several important issues of the accreditation process and quality assurance in engineering and technology education.
- Internet search for accreditation processes and their implementation in engineering courses.
- Search for various existing systems of accreditation worldwide in engineering and technology courses.
- Search for an effective scientific model of accreditation in engineering and technology education.

Review of Existing Accreditation Bodies in Higher and Technical Education Worldwide

In recognition of the impact of higher education in economies of the world, several quality assurance policies have been established and implemented worldwide through various international, regional and national agencies. The following are a few examples of such establishments around the world.

International Network for Quality Assurance Agencies in Higher Education (INQAAHE)

The International Network for Quality Assurance Agencies in Higher Education (INQAAHE) is the most representative association in the world with a global membership base. It has been established to collect and disseminate information on current and developing theories and practices in the assessment, improvement and maintenance of quality in higher education [10][22].

Accreditation Board for Engineering and Technology (ABET)

The ABET was established to serve the public by the promotion and advancement of engineering education, applied science, computing, engineering and technology through the development of better educated and more qualified persons in their respective fields [23]. The ABET has introduced several sets of criteria for the accreditation of various programmes, such as *Criteria 2000*, which was approved in 1998 for the accreditation of engineering programmes in different countries [24].

European Cooperation for Accreditation (EA)

Two former organisations of European national accreditation bodies, namely the European Accreditation of Certification (EAC) and the European cooperation for the Accreditation of Laboratories (EAL), have joined forces to form the European Accreditation (EA). This new organisation covers all European conformity assessment activities within Europe and covers testing, calibration and inspection. The EA links 25 accreditation authorities across 18 countries [25].

Engineering Council, UK

In the United Kingdom, the Engineering Council, UK (ECUK) regulates the engineering profession through 35 licensed engineering institutions. The quality assurance process in engineering education has been recently modified by the board of the ECUK and the updated framework of accreditation is effective as of March 2004. The Engineering Council, UK also participates in two important international organisations: the European Federation of National Engineering Association (FEANI) and the International Engineers' Meeting (IEM). The ECUK recognises several engineering education programmes in those countries, which are signatories to the following important international agreements:

- The Washington Accord;
- The Sydney Accord;
- The Dublin Accord [26].

European Network for Quality Assurance in Higher Education (ENQA)

The European Network for Quality Assurance in Higher Education (ENQA) is one of the regional networks for quality assurance in higher education in Europe. It has been established to promote European cooperation in the field of quality assessment and quality assurance [27].

International Laboratory Accreditation Cooperation (ILAC)

The International Laboratory Accreditation Cooperation (ILAC) affirms itself to be the world's principal international forum for the development of laboratory accreditation practices and procedures. Most of the laboratory accreditation agencies throughout the world are members of the ILAC, which promotes laboratory accreditation as a trade facilitation tool and assists developing accreditation schemes [28].

REVIEW OF ACCREDITATION BODIES IN THE ASIA-PACIFIC REGION

This section will review past and existing accreditation agencies and systems for the assessment of higher education systems in the Asia-Pacific region.

Asian Accreditation Accord (AAA)

At the regional inaugural meeting of the Asian Accreditation Accord (AAA), several Asian countries signed a statement of cooperation to facilitate the accreditation of academic programmes through the recognition of respective processes. This agreement also committed signatories to pursue mobility of human resources so as to enable cooperation and collaboration between Asian higher educational institutes on a bilateral or multilateral basis for mutual economic and technological growth [29].

Asia Pacific Laboratory Accreditation Cooperation (APLAC)

Along the same lines of the ILAC, the Asia Pacific Laboratory Accreditation Cooperation (APLAC) was founded in order to recognise laboratory accreditation schemes throughout the Asia-Pacific region. The APLAC is recognised by the Asia-Pacific Economic Cooperation (APEC) as a Specialist Regional Body (SRB). The APLAC fosters the development of competent laboratories and also facilitates the mutual recognition of accredited tests, measurements and results [30].

INVESTIGATION OF IMPORTANT ACCREDITATION ISSUES FOR ENGINEERING COURSES IN THE USA

One of the great strength of the American higher education system is the voluntary, non-governmental and highly effective accreditation system, which includes both regional and professional accreditation, such as the ABET [31]. The ABET, which comprises almost 28 engineering professional societies, is responsible for the accreditation of engineering and technology courses in USA. The ABET established accreditation criteria for six countries under a mutual agreement in the late 1980s and, since then, these agreements have been extended to many countries worldwide [24]. A new set of criteria for accrediting engineering programmes was approved by the ABET in 1998, called Engineering Criteria 2000. Specific accreditation criteria and procedures, including Engineering Criteria 2000, are frequently revised and modified by the ABET for their effective and efficient implementation. Several engineering and technology institutions in the USA have already been reaccredited under the assessment standards of the ABET's Engineering Criteria 2000 (EC2000). ABET's Criteria for Accrediting Engineering Programmes (effective for evaluations during the 2004-2005 Accreditation Cycle) have been recently introduced [14].

INVESTIGATION OF IMPORTANT ACCREDITATION ISSUES FOR ENGINEERING COURSES IN EUROPEAN INSTITUTIONS

Accreditation and quality assessment processes in Europe have their roots in the 1950s, when several initiatives at regional and national levels were taken in the form of educational audits in order to assess pedagogical skills in higher education [32]. However, an authentic need for quality assurance in higher education was identified in the early 1990s due to the impact of the globalisation of education and relevant changes in the university education system. After the Bologna Declaration signed by European nations in 1999, the process of international accreditation commenced in 2004 in several countries, like Germany, Norway, Switzerland, Spain, Austria, Ireland and Poland [33].

The following are important case studies to investigate important issues of accreditation for European nations.

Case Study 1: Review of the Accreditation System in Germany, Case Study of Hochschule Wismar – University of Technology, Business and Design, Wismar, Germany

The old procedure of accreditation and quality assurance in Germany was less efficient due to its lack of flexibility and transparency [34]. In each State, most of the German Diploma Certificate and Undergraduate courses were approved and recognised by the respective State Minister of Higher Education and Science [35]. Recently, several bachelor and master programmes have been introduced in the German higher education system; as such, the accreditation of these courses is needed. In Germany, before the Bologna Declaration on 19 June 1999, the recognition of various degree courses was carried out by a specialised body that has been established in every Federal State, called *Rahmenprüfungsordnung*, that is the examination regulation body.

In November 1999, the accreditation council in Germany formulated minimum standards and criteria for the accreditation of accrediting agencies, as well as various undergraduate and graduate study courses. This council was formed on a trial basis on the recommendations of the Conference of the Ministers of Education (KMK) in 1998. Furthermore, the Association of German Engineers (VDI) took initiatives and formed a dedicated accreditation agency for engineering science courses in 1999, called the Accreditation Agency for Study Courses in Engineering and Computer Science (ASII) [34].

After the merging of the ASII with the Accreditation Agency for Study Courses in Chemistry, Biochemistry and Chemical Engineering (A-CBC) in September 2002, the new German Accreditation Agency for Engineering, Informatics/Computer Science, the Natural Science and Mathematics (ASIIN) was formed [34]. The ASIIN, a non-profit, registered association, was officially accredited by the German Accreditation Council on 12 December 2002 and also joined the Washington Accord (as a provisional member) in 2003.

An advanced research study will be carried out as a case study at the Hochschule Wismar, Wismar, Germany, in order to investigate the strengths and weaknesses in the German accreditation system.

Case Study 2: Review of the Accreditation System in Poland, Case Study of Gdynia Maritime University, Gdynia, and Technical University of Częstochowa, Częstochowa, Poland

The higher education system in Poland continues to undergo several radical changes since the last decade. This is due to the educational reforms, such as the establishment of new Higher Education Professional Schools (HEPS), the restructuring of Polish industry, the increasing number of unemployed, the entry into the European Union (EU), etc [33][36][37].

In Poland, the two methods of accreditation that have been implemented at technical universities are as below:

- The State Accreditation Commission (SAC) from the Ministry of National Education and Sport;
- The Accreditation Commission for Technical Universities (ACTU), appointed by the Conference of Rectors of Polish Technical Universities [33].

Although the objectives of both accreditation systems are the same, there is a difference in their procedure or the process of accreditation.

The State Accreditation Commission (SAC) which is a mandatory body of accreditation in Poland addresses several issues and meets challenges in the process of accreditation of higher professional education. These challenges include various elements of the higher professional schools such as, the openings of new higher professional institutions, two grade and binary education system of studies, stability of academic staff, infrastructure standards, professional specialisations, etc [38].

Apart from many other factors, the two important concerns that influence the quality of higher engineering education in Poland are the personnel and students of the higher education stream [39]. This is due to the major growth and dynamic expansion of higher education in Poland in the last decade, that is after the fall of the communist system (1989) and the introduction of the

Professional Higher Education Act by the Polish parliament in 1997.

A detailed review of the Polish accreditation system of the higher engineering education will be carried out and the important strengths and weaknesses will be investigated. This will be further elaborated with the help of case studies at the two Polish institutions.

Case Study 3: Review of the Accreditation System in the UK, Case Study of Glasgow Caledonia University, Glasgow, Scotland, UK

The quality measurement and assurance in the UK higher education system began in 1964 with the establishment of Council for National Academic Awards (CNAA) [12]. However, the introduction of modular systems, as well as a greater emphasis on the traceable quality assurance, in the last decade have been the major changes evidenced in the programme structure in the UK higher education system [40].

An important feature of the UK Accreditation system is its well-designed range of Professional Development policies. These policies encourage good engineering practices in order to foster the professional competences of registered engineers throughout their working life [26]. The methodology designed in the assessment process includes the Initial Professional Development (IPD) phase, which focuses on the need to acquire competences in order to qualify as a professional engineer, by acquiring the skills and competences that are necessary to satisfy the professional review.

A detailed review will be carried out to investigate the important strengths and weaknesses in the existing accreditation system of the higher engineering education in the UK.

Case Study 4: Review of the Accreditation System in Russia, Case Study of Tomsk Polytechnic University, Tomsk, Russia

In Russia, before the 1990s, the integrated assessment procedure of higher educational institutions involved three important steps, namely licensing, attestation and national accreditation [41]. However, due to the increasing trend of the internationalisation in education, the Coordination Board of Accreditation (CB) and the Independent Accreditation Centre (IAC) for engineering and technology educational programmes and courses were established in 1992 [42]. At present, there are two different systems of accreditation in Russia. The State accreditation system is an old system of accreditation from 1936 and is carried out under the auspices of the Russian Ministry of Education. The independent or public accreditation system in engineering education, which was formed in 1992, is carried out by the Independent Accreditation Centre for Engineering Disciplines (IAC) [43].

The Coordination Board of Accreditation (CB) also included the Certification Centre of Specialists and Independent Accreditation Centres. The IAC, which is the first private, independent accreditation centre in Russia, has developed criteria for the evaluation of engineering educational programmes and was able to accredit several programmes of various universities in the European and Asian parts of the Russian Federation. Recently, the IAC and its Siberian Branch achieved a mutual understanding between the ABET and Tomsk Polytechnic University (TPU) in order to pursue international cooperation in the field of engineering accreditation.

In 1999, the Russian national system of professional public accreditation introduced new changes in its development with the accreditation of professional educational programmes in management, economics and finance [41]. More recently, in 2003, Russia joined the Bologna Declaration.

Further review of the accreditation system of the higher engineering education in Russia will be carried out in order to investigate the important strengths and weaknesses.

INVESTIGATION OF IMPORTANT ISSUES OF ACCREDITATION FOR ENGINEERING COURSE IN THE ASIA-PACIFIC REGION

In this section, important issues of accreditation and quality in engineering education in the Asia-Pacific region will be discussed and reviewed. This will be further elaborated with study cases of a few engineering institutions in the Asia-Pacific region.

Case Study 5: Review of the Accreditation System in Australia, Case Study of Monash University, Melbourne, Australia

Unlike most Asian universities, all Australian universities are self-accrediting, devise their own courses and award their own degrees without any special approval [44]. However, the independent, non-profit, national agency called The Australian Universities Quality Agency (AUQA), incorporated in 2000, promotes quality assurance in the Australian higher education system by conducting quality audits and self-accreditation [45]. Engineers Australia, formerly known as the Institution of Engineers, Australia (IEAust), is responsible for the accreditation of engineering degree courses [46]. The accreditation process outlined in the current manual of Engineers Australia primarily focuses on the quality assurance (QA) procedures and practices of an institution [47].

Further review of the accreditation system of Australia higher engineering education will be carried out in order to ascertain its important strengths and weaknesses.

Case Study 6: Review of the Accreditation System in Taiwan, Case Study of National Changhua University of Education, Changhua, Taiwan

In Taiwan, the Ministry of Education has published a White Paper on technology and vocational education in which 10 policies on the present system of vocational and technical education have been introduced [48].

Further review of the accreditation system of the higher engineering and technology education system in Taiwan will be carried out, as well as an investigation into the important strengths and weaknesses in existing models.

Case Study 7: Review of the Accreditation System in India, Case Study of Anna University, Chennai, and University of Pune, Pune, India

India has made significant progress in many human endeavours, including education. Literature and statistical research have shown that there is growth of higher, as well as in technical, education after independence (1947) in India. Furthermore, this growth was quite exponential in the 1980s and 1990s. This is primarily due to the opening of several engineering and technology colleges on a non-aided or non-grant basis after the 1983 education policy of the Government.

The National Accreditation and Assessment Council (NAAC) is responsible for the assessment and accreditation of higher educational institutions in India, including engineering and technology. The NAAC is an autonomous body established by the University Grants Commission (UGC) on the recommendations of the National Education Policy of 1986 [49].

A detailed review of the accreditation system of the higher engineering education in India will be carried out and the important strengths and weaknesses will be investigated.

TESTING OF HYPOTHESIS

The hypothesis will be tested using a literature search, search of existing systems of accreditation and using the data collected from the study cases.

IMPORTANT ISSUES OF ACCREDITATION AND ASSESSMENT

Results of a survey of the relevant literature and observations indicate that various assessment models have been developed regionally, as well as internationally, in order to accredit engineering courses. However, most of these models seem to be non-uniform, too complex, non-transparent and, moreover, non-scientific! The economic globalisation and internationalisation of engineering education, the increasing number of student intakes, the development of new courses and the increasing trend of distance or online education are the main concerns that are associated with the accreditation process. These issues are discussed in detail below.

A Scientific Model of Accreditation and Assessment

The most important issue of the accreditation and assessment of engineering education is the need for a scientific, transparent and effective model of accreditation that can be used to assess professional skills and attributes of engineering graduates. There is a strong need for open-ended, well-structured assessment programmes in order to accredit engineering courses.

The literature search has shown that one of the oldest efforts for designing such a model can be found in the establishment of the European Federation of National Engineering Associations (FEANI) in 1951 [50]. The FEANI, a federation of professional engineers that unites national engineering associations from 26 European countries, brings together more than 80 national engineering associations.

The main objectives of FEANI are to affirm the professional identity of European engineers by ensuring that professional qualifications gained by engineers in European states are acknowledged in Europe and beyond. The FEANI, also striving for the unity of the engineering profession in Europe, works in cooperation with the other international organisations that deal with engineering matters.

Engineering Professionals: Global Perspectives

The internationalisation of higher education, as well as the integration of national economies, have generated the increasing requirement for the global mobility of engineering professionals. As a result, it is essential to develop a universal model of international accreditation or licensing for the assessment and recognition of engineering professionals worldwide [51].

The literature search has shown very little evidence of the establishment of such international accreditation fora. For instance, the establishment of the Foundation for International Accreditation and Certification Assistance (FIACA) in Russia is an action-oriented step towards the enhancement of Russian higher education into the world community [52]. However, most of these developments focus on regional developments or individual benefits. There are several concerns associated with the licensing of engineering professional for international practice; most of these concerns are beyond the objectives and aims of the Washington Accord and the Bologna Process [53].

As described by Kasuba and Vohra, the formation of a uniform international accreditation model is very much complex due to economic, political and jurisdictional issues. However, this may be possible with the initiatives of neutral, international organisations, such as the UNESCO International Centre for Engineering Education (UICEE), which can facilitate the establishment of an international accreditation or licensing model to promote and benefit global mobility in international engineering education [51].

Accreditation Agencies

Apart from the fixed situation, where there is choice, the major concern in the accreditation of engineering education for an institution is to select an appropriate accreditation body. Since there are several accreditation agencies and systems established at the national, regional and international levels, the institution has to approach an appropriate authority for assessment.

In order to avoid this confusion, there is a strong need to establish a dedicated accreditation and quality assurance forum for engineering and technology education in different regions. For example, an Asia-Pacific Board of Accreditation and Quality Assurance in Engineering and Technology Education (APBAET) can be formed in order to cater for the qualitative and quantitative assessment of engineering and technology education in the Asia-Pacific region [54]. However, these types of regional accreditation board must be linked with international accreditation agencies.

Growth of Student Intake and Changes in Learning Styles

It has been observed that learning is becoming a huge market worldwide. There has been a tremendous expansion of higher education over the last two decades. The number of students studying higher education, internationally, has increased from 51 million in 1980 to 82 million in 1995, and the growth is 61% [55]. Due to rapid industrialisation and fast economic growth, engineering and technology education is also developing at an accelerated rate worldwide. There has also been a sizeable expansion in student enrolments in engineering programmes over the last two decades.

Moreover, the trend of instructional deliveries in higher education has been changing rapidly from traditional classroom-based to online or Web-based education. Numerous studies have shown that distance and online learning in the USA has been strongly boosted in recent years. This is especially in areas like engineering, due to factors such as a very good job market and the lack of time to complete an engineering course in traditional settings. In the USA, several universities offer full programmes of higher education courses utilising Internet-based technologies for instructional delivery. Increasingly, more engineering courses are developing as online and distance learning programmes and these online universities are also getting accredited [56].

Assessment of Engineering Curricula and Courses

Traditional assessment with written examinations is still a preferred method of assessing students; however, new technology can be implemented to assess students' performance, such as online surveys, peer reviews, mock interviews, etc. Designing and implementing relevant assessment models in engineering courses are complex tasks, since engineering programmes include laboratory and project work along with theory. Several attempts have been made to develop a method for the assessment of engineering students. For instance, an authentic assessment strategy has been used in the Multi-Disciplinary Industry Project (MDIP) at Monash University, Melbourne, Australia, over several years [57].

Faculty Issues and Staff Assessment

Academic staff is an important part of any engineering education system and it is important to judge the competences and faculty resources available in an engineering institution. The ABET has developed various faculty workshops in order to understand and explore accreditation programmes in engineering education in the USA. However, there are no such workshops developed in other regions globally. It is envisaged to devise various regional periodic workshops for the faculty (including non-teaching) in a similar manner in other regions.

Financial Structure and Auditing

The funding of higher education has been hotly debated recently. As pointed out by Morley, higher education systems in Western Europe are dominated by public universities, with 95% of students preferring public universities. In contrast to this, private higher education is one of the fastest growing segments in the post secondary education sector globally [55].

Financing higher and technical education is the main problem in most developing and underdeveloped countries. Every nation seeks to globalise its local and national standards of engineering and technology education so as to make it competitive in an international market. It is essential to assess the financial resources in order to ensure the quality of engineering education. In order to devise an appropriate framework, the proposed accreditation model must include a thorough assessment and auditing of all available financial sources and budget of the institution.

Several countries in the Asia-Pacific region, like Australia, New Zealand and Singapore, to name a few, have already developed education as a sizable industry, becoming an important source of national income. These countries have already redesigned their fee structure for higher education, and most of the universities are being, in a sense, privately funded. Other Asian countries, for instance India, where student enrolments are very high and most universities are government-funded, are also adopting financial autonomy for higher and technical education. OECD data on educational expenditure shows that Australia has the largest private funding education system after South Korea, the USA and Japan [58].

Learning Outcomes

A survey of relevant literature on students' learning outcomes shows that graduates from university courses lack important skills, such as communication, decision-making, problem solving, leadership, emotional intelligence, social ethics, etc. Also, these students do not have the requisite ability to work with people from different backgrounds [57].

Indeed, the workplace performances of engineering graduates have been a constant subject of criticism. One study carried out on successful engineering graduates in their first few years of full-time work identified the capabilities essential for the most successful engineering practice [59]. Unfortunately, there are only few instances of such studies at workplaces. It is essential to use feedback gained in the process of accreditation from the workplace and graduate students in order to improve course structures.

There is increasing evidence of a mismatch between graduate students' skills during their studies and those needed in the workplace. Various assessment models devised in engineering education have not revealed the qualitative assessment of the necessary attributes associated with graduate students. It is essential to include these assessment criteria in the accreditation framework, especially since engineering graduates need to work within multicultural and multinational workplace environments.

The Globalisation of Engineering and Technology Education

It has also been observed that the process of the internationalisation of engineering and technology education in the world is directly affected by the increased liberalisation of trade and professional services. As a result, the application of a proper accreditation model, which will be internationally recognised, is urgently required for the mobility of engineering and technology instructors and students around the world.

Assessment of R&D Activities

Comprehensive literature searches have shown that the total R&D expenditure by industry and government in many developing and underdeveloped countries stands at very low percentage, as compared to Europe and the USA. Further, the number of scientists, engineers and technicians engaged in R&D activities is also not satisfactory in many underdeveloped and developing nations.

Literature searches have also shown very little evidence of the assessment of R&D activities and facilities available in an engineering institution. Therefore, it is essential to include the criteria of R&D assessment in the accreditation framework, which, in turn, may foster the development of joint research and development activities around the globe. This may also enable access to modern facilities and infrastructure in R&D activities at engineering institutions.

Design and Development of a Scientific Model of Accreditation and Assessment

The most important part of the accreditation process of engineering education is the design of an effective and scientific model of accreditation that can be used for the assessment of engineering programmes. In order to measure the quality of engineering education, the most traditional process involves a measurement of the *Output* part of this cycle, that is the quality of engineering graduates in terms of educational values, such as academic results and workplace recruitments. The quality of engineering and technology education can be analogous to industry, as illustrated in Figure 1.

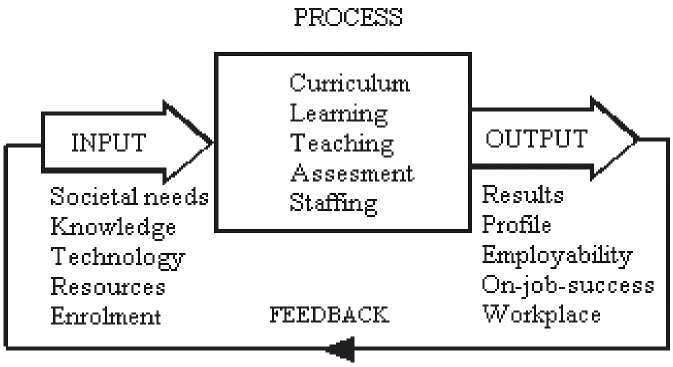

Figure 1: Diagram showing the educational cycle.

Any standard industrial activity includes three different stages, such as the *Input*, the *Process* and the *Output*, where feedback closes the loop. In this process, feedback gained from the *Output* can be utilised to improve the quality of the *Process*.

This model has also been adopted for the quality assessment of education structures. A literature review has shown that most of the techniques suggested and developed to improve the quality of engineering education focus on the *Output* part of the process, neglecting two other important stages.

The proposed accreditation model will include a strategy for the assessment of a comprehensive educational process in three different parts. An outline of the model is given below.

PART 1: AN EFFECTIVE ASSESSMENT OF THE INPUT PROCESS

The assessment of the *Input* process of the educational cycle contains a review and assessment of the important parameters related to students' intake or students' enrolments into an engineering educational process, etc, and this can be further comprised of the aspects described below.

Design and Development of an Effective Assessment of the Infrastructure Standards

This particular part of the design will include a strategy for an assessment of the basic needs and infrastructure standards associated with the engineering education at the given institution or university, such as the following:

- Societal needs;
- New knowledge;
- Advancing technologies, etc.

Design and Development of Effective Assessment of an Institution's Infrastructure

The institutional infrastructure is of utmost importance in order to facilitate the learning process of engineering and technology programmes. This will include assessment of the following:

- Institutional assets/properties and required infrastructure, such as classrooms and laboratory spaces;
- Use of advanced technologies;
- Human and material resources;
- Library and computing resources, etc.

Assessment of Student Intake Strategy and Process

The assessment of the process of student intakes into the engineering programmes is also important. This will include the following:

- Student enrolment processes;
- Student fees structures;
- Student eligibility criteria, etc.

PART 2: AN EFFECTIVE ASSESSMENT OF EDUCATIONAL PROCESSES

It is envisaged to include a strategy for an assessment of the educational *Process* that lies in between the *Input* and the *Output*, where teaching/learning is facilitated. It has been claimed by several research results on the educational evaluation process that the study of student and staff evaluations for the quality of learning and teaching performances is very much essential in the educational process. This part of the model will include an assessment strategy for both learning (student evaluation) and teaching (staff or instructor evaluation) performances in the educational process. It will consist of the following elements.

An Effective Assessment of Engineering Curricula

The most important part of the educational process is the design and implementation of engineering course curricula. The success of any engineering or technology programme can depend on effective curricula that will facilitate students' core knowledge and professional skills required at the workplace. The following factors will be considered while formulating assessment strategy for the engineering curricula:

- Academic content of course curricula;
- Design and practical components of curricula.

Assessment of Learning Styles and Learning Methods

While designing the strategy for the assessment of learning styles and learning methods in the educational process, the following essential elements will be considered:

- Assessment of classroom attendance and activities;
- Practical assessment of laboratory work during the course curriculum;
- An assessment of project work/seminar/teamwork/self-study learning during the course curriculum;
- Students' performance assessment methods and their implementation;

- Assessment of student-student and student-faculty interaction methods.

Assessment of Staffing and Teaching Qualities

It is also envisaged to include the proper assessment techniques for staff (instructors) and teaching qualities. This will include the following points of consideration:

- Assessment of the staff recruitment criteria;
- Assessment of staffing facilities and resources;
- Assessment of continuing professional development of faculty, including in-service workshop/training programmes.

PART 3: AN EFFECTIVE ASSESSMENT OF LEARNING OUTCOMES

The assessment of learning outcomes, or the *Output* component of the educational cycle, is associated with the students' output after finishing the course curricula. This part of the accreditation model will include the essential elements listed below.

Assessment of Academic Results and Employability

In order to assess learning outcomes in the process of accreditation, it is essential to measure academic success and employability rates of students of an engineering programme. This will be include the following important components:

- Academic results;
- Employability;
- On-the-job success rate;
- Social and workplace activities, etc.

Design and Development of an Effective Tool for the Assessment of Engineering Professional Skills

A literature review has shown little evidence of the assessment of the required professional skills associated with engineering and technology graduates in existing accreditation methods utilised worldwide. For example, at Tomsk Polytechnic University, Tomsk, Russia, approaches to specialist training in the area of high technologies have been carried out and also used during the educational process in order to meet industrial needs and increase the scientific and technical potential of higher educational institutions in Russia [60]. In order to enhance the mobility and licensing, it is also important to assess engineering design skills and associated elements of the professional engineer who is capable of working in the global context [61].

In order to assess and measure required engineering professional skills and profile of graduates, the accreditation model will also include strategies in design such as those detailed below.

Design and Development of a Methodology for the Standard Professional Profile of Engineering Graduates

The professional profile will assess the following attributes and skills:

- Generic skills;
- Professional skills;
- Engineering practice;
- Business and communication skills;
- Leadership and managerial skills;
- Personal skills, such as working with others and self-study attitudes;
- Problem-solving skills, etc.

Assessment of Important Learning Attributes and Skills

It is important to assess important learning attributes and skills gained by engineering graduates. Therefore, it is envisaged that the proposed model will also include a strategy for the assessment of various essential attributes and skills, such as:

- Knowledge of basic and advanced engineering subjects;
- New knowledge gained;
- Employability;
- On-the-job success rates;
- Social and workplace activities, etc.

Evaluation of the Accreditation Model, Review and Corrections

An evaluation of the accreditation model will entail a review and corrections, including the following:

- An evaluation and review of the proposed accreditation model for effectiveness and consistency will be conducted;
- The necessary corrections in the model for better performance will be made.

DISCUSSION

The scientific and practical aspects of the devised accreditation and assessment model for the quality assurance in engineering and technology courses will be thoroughly presented and discussed in this section.

Conclusions, recommendations and opportunities for future work will be presented, as well as the requisite bibliography and references.

CONCLUSIONS

A literature search has revealed strong evidence that the quality of higher education of a country impacts significantly on its economic progress. The lack of quality higher education has clearly influenced the overall progress of developing and underdeveloped nations. Education is increasingly being considered as an investment for the collective future of societies and countries.

Accreditation, which emerged as a national phenomenon in 1906, began as a relatively simple idea; however, it has since changed in the direction of a complex evaluative tool. A literature search on the accreditation and assessment of higher education shows that there is no common agreement or criteria that can be used in the accreditation and assessment of engineering education.

The integration of laboratory procedures differentiates engineering courses from other disciplines. As a result, laboratory accreditation is a very important and essential factor in the quality of engineering education. A survey of literature and relevant observations made indicate that various assessment models have been developed regionally, as well as internationally, in order to accredit engineering courses. However, they lack the standard scientific requirements of the accreditation process. Although to design and formulate a standard and uniform accreditation process is a complex and difficult task, there is an urgent need for the development of a uniform, user-friendly, transparent and scientific accreditation model for engineering courses that will comprise of all three parts of the educational cycle, namely the *Input*, the *Process* and the *Output*. A brief outline of this project is described in this article. It is envisaged that a scientific methodology to assess the standard professional profile of engineering graduates will also be developed as part of the project.

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