

Developing Engineering Qualifications Within the South African NQF: a View from ECSA

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Abstract

The paper traces the development of engineering as a profession to the present day. Current drivers of engineering qualifications are identified, including the Higher Education Qualifications Framework. A possible evolution path is sketched for engineering qualifications and professional designations. Experiences are recounted of standards setting and quality assurance within NQF prescriptions. We demonstrate that engineering professional qualifications are compatible the NQF. Professional designations, by contrast, are best left under the statutory regulation of the profession itself.

Historical Perspective on Engineering Qualifications

The beginning of engineering is difficult to fix other than to identify early artefacts that are useful to people, that exploit or counter the forces of nature and required ingenuity in their creation. Examples from antiquity include aqueducts, sailing ships, fortifications, war machines and canals. The Industrial Revolution, loosely bracketed by the years, 1750-1850 saw the emergence of distinct threads of engineering activity that became known as civil, mechanical and electrical engineering. These early engineers were essentially practical people. Over time, they became professionals: society accorded them respect and status for their contributions. The next hundred years saw the Second Industrial Revolution. Practical engineering developed into science-based engineering. Fundamentals and useful knowledge were systematized and engineering developed its own body of knowledge. Engineering schools came into existence. New engineering disciplines emerged, for example chemical engineering. From the 1950s, developments in microelectronics, computing and communications signaled the transition to the Information Revolution – a development that had a profound effect on engineering practice and on society generally. Engineering became an enabler of globalization and is practised on a global scale to global standards. As the

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developments enabled by engineering place more strain on the planet, the profession must play a key role in helping society face the challenges of a sustainable future.

Defining engineering as an activity and engineers as practitioners requires five steps (ECSA 2005c). First, engineering encompasses initiatives, services and the solution of problems that are of importance to society and the economy.

Second, engineering activity brings benefits through exploiting natural resources, harnessing energy, using materials with beneficial properties, using machinery and equipment, transferring, storing and processing information, constructing, operating and maintaining infrastructure and plant, and organising and controlling systems or processes. These actions involve risks, requiring engineering activity to be conducted with due care for economy, ethics, safety, health, the environment and sustainability.

Third, characteristic engineering functions include designing materials, components, systems or processes; planning the capacity and location of infrastructure; investigating, advising and reporting on engineering problems; improvement of materials, components, systems or processes; managing or operating plant and processes; managing implementation or construction projects; implementing designs or solutions; and research, development and commercialization of products.

Fourth, engineering activity requires a body of knowledge and distinctive competencies. The body of knowledge is based on mathematics, basic sciences, engineering sciences¹, information technology and contextual knowledge including legal, financial and regulatory aspects. Distinctive competencies include identifying problems and designing solutions, managing activities, addressing impacts of solutions and activities on people and the environment, acting ethically, applying judgement and taking responsibility.

Fifth, the practice of engineering activities at professional level involves a number of roles that have evolved over time. As engineers acquired scientific underpinnings, technicians took over work that could be performed according to established procedures. As many

¹ *Engineering Sciences* have roots in the mathematical and physical sciences, and where applicable, in other basic sciences but extend knowledge and develop models and methods in order to lead to engineering applications and solve engineering problems (ECSA 2004).

technologies became established, the need was seen for a role intermediate between the technician and engineer, namely the technologist (RSA 1978). Modern requirements are recognized in the *categories of registration* specified in the Engineering Profession Act (EPA) (RSA 2000): Professional Engineer, Professional Engineering Technologist, Professional Engineering Technician, and Professional Certificated Engineer. These categories form the *engineering professional team*. They are supported by a number of engineering support occupations such as draftsmen, testers, inspectors and supervisors.

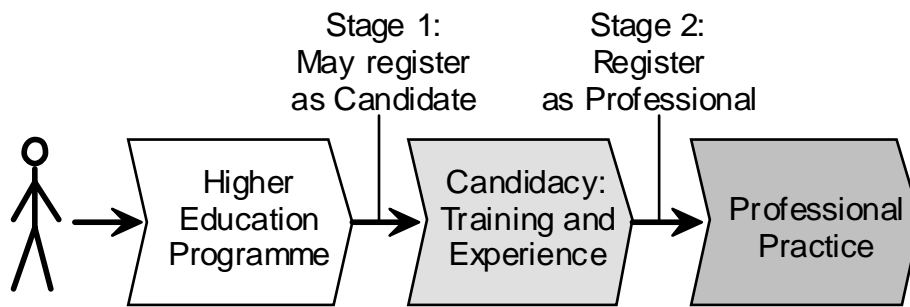


Figure 1: Process of Professional Development

The *process of professional development* in engineering has three principal phases shown in Figure 1 for a category of professional. First, engineering education leads to a qualification accredited for the category of registration. Meeting educational requirements is called *Stage 1* of professional development. Second, the candidacy phase, consisting of training and experience while employed, develops the professional competencies to *Stage 2*, where the person becomes professionally registered. Demonstration of competency at *Stage 2* is based on actual performance of engineering work.

Qualifications meeting *Stage 1* requirements, are termed *professional qualifications*: they recognise learning achievement toward gaining professional registration (SAQA 2006b,c). These are generally higher education qualifications and, like any other qualification, are perpetual and cannot be withdrawn. At *Stage 2*, the applicant for registration must demonstrate the competency required for the category. A successful applicant is registered and is granted a title such as Professional Engineer. This title signifies to the public the competence of the person, confers the right to practice and imposes obligations on the holder who must conform to a code of conduct, must practice only within the limits of competency and must maintain registration through continuing professional development. The title, along with the right to practice, may be given up or taken away if obligations are not met. Because

of intrinsic differences between these titles and Stage 1 qualifications, such titles are referred to as *professional designations* (SAQA 2006c).

This paper examines the engineering professional qualifications and professional designations following two themes. Theme 1 describes the engineering qualification and professional designation structure as it has evolved. Theme 1 also examines drivers of change and current developments to meet changing needs. Here, we first encounter the influence of the National Qualifications Framework (NQF) and other national initiatives. Theme 2 examines the present and evolving engineering structure within the concepts, thinking, rules and constraints of the NQF. Matches and mismatches between requirement of the NQF and those of the profession are identified.

Theme 1: Developing Engineering Qualifications and Professional Designations

In this theme we use the word *developing* in the sense of the long and continuing evolution of engineering science, technology, education and practice and roles that are fit for purpose in the prevailing environment. These roles have distinctive competencies that have common classes of outcomes, for example problem identification and solution, but are exercised at different levels in various categories. Within a category, the professional qualification must provide a basis that would, as illustrated in Figure 1, enable the aspiring professional to enter a realistic programme of training and experience and thereby attain the competency required for registration. The set of engineering professional qualifications and professional designations must therefore be located in a coherent framework.

Present Engineering Qualifications and Professional Designations Framework

The three generic categories of engineering professional recognised by ECSA and in most jurisdictions have distinctive characteristics summarised in Table 1. Noteworthy is the gradation of attributes observed when reading across the three categories. For example, engineers are expected to solve problems from first principles, technologists by applying technologies and technicians by applying established procedures. In addition, South African health and safety legislation calls for the Certificated Engineer, also afforded professional status in the Engineering Profession Act. The Certificated Engineer requires basic competence equivalent to the technologist but is specialised in engineering-related occupational health and safety and the effective operation of mining and manufacturing.

Table 1: Characteristics of three engineering categories of engineering professional

<p>Professional Engineers are characterised by the ability to solve problems, develop components, systems, services and processes through creativity, innovation and the application of fundamental and engineering principles.</p> <p>They provide technical and commercial leadership through well-developed interpersonal skills.</p> <p>They work independently and responsibly, applying original thought and judgement to technical and risk-based decisions in complex situations.</p> <p>Professional Engineers have a broad, fundamentals-based appreciation of engineering sciences, with depth in specific areas, together with knowledge of financial, commercial, legal, social and health, safety and environmental matters.</p>	<p>Professional Engineering Technologists are characterized by the ability to apply established and newly developed engineering technology to solve problems, develop components, systems, services and processes.</p> <p>They provide leadership in the application of technology and commercially and have well-developed interpersonal skills.</p> <p>They work independently and responsibly, applying judgement to decisions arising in the application of technology to problems and associated risks.</p> <p>Professional Engineering Technologists have an understanding of engineering sciences underlying a deep knowledge of specific technologies, together with financial, commercial, legal, social and health, safety and environmental matters.</p>	<p>Professional Engineering Technicians are characterized by the ability to apply proven, commonly understood techniques, procedures, practices and codes in support of engineering activities.</p> <p>They manage and supervise engineering operations, construction and activities.</p> <p>They work independently and responsibly within an allocated area or under guidance of an engineer or technologist.</p> <p>Professional Engineering Technicians have working understanding of engineering sciences underlying the techniques used, together with financial, legal and health, safety and environmental methodologies.</p>
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Defining Engineering Competency, Outcomes and Levels

The profiles given in Table 1, read with the five characteristics of engineering activity listed in Section 1, provide purpose statements for the competency standards for the three categories of engineering professional. The Stage 2 outcomes that demonstrate that a person has the competence to fulfil the purpose fall into four groups:

- A. Knowledge-based engineering *problem solving*, including the analysis and identification of problems, synthesis of solutions and the use of fundamental, specialist and contextual knowledge.
- B. *Management of engineering activities*, focussing on people, resources, finances, processes, teamwork, leadership and communication.
- C. Recognising and addressing the *effects of engineering activities*; meeting legal and regulatory requirements; protecting the health and safety of persons in the course of engineering activities; and conducting engineering activities ethically.
- D. Exercising sound *judgement* in the course of engineering activities and being *responsible* for making decisions.

A fifth form of competence has been added:

- E. The ability to undertake *professional development* activities sufficient to maintain and extend competence.

The level of fundamental and engineering science knowledge referred to in A is typified by accredited qualifications that comply with Stage 1 educational standards for the category. Stage 1 outcomes relating to group A include knowledge-based problem solving, design and investigation. Outcomes for Groups B, C and D cover communication and an appreciation of ethics, the impacts of engineering activity and professionalism. Ten outcomes are defined for BEng-type qualifications (ECSA 2004) and have been benchmarked against the International Engineering Alliance² (IEA) Graduate Attributes (IEA 2005).

Outcomes-based standards have been developed for the technologist (ECSA 2005a) and technician (ECSA 2005b) but implementation awaits the migration of qualifications from the NATED 151 specification (RSA 1999) to the Higher Education Qualifications Framework (RSA 2007). These standards are supported by level descriptors described below.

Structure of Engineering Qualifications and Professional Designations

The existing structure of engineering qualifications and professional designations is shown in Figure 2. The figure shows the normal or *benchmark routes* to registration in each category: an accredited programme followed by a *candidacy programme*, leading to registration.

The Professional Engineer and Professional Technician pathways conform to the two-stage model described in figure 1. The BEng-type degree accredited by ECSA provides the benchmark for the Stage 1 educational requirements (ECSA 2004). These may also be satisfied by a programme accredited by a signatory to the Washington Accord or by individual evaluation to establish substantial equivalence. The benchmark route to registration requires a programme of training and experience that is not less than three years in duration. The applicant then prepares evidence for assessment detailing experience and achievement against the requirements for registration. The application is assessed by peers who are registered in the category. An applicant meeting the requirements is then registered as a Professional Engineer.

² The International Alliance includes the Washington, Sydney and Dublin Accords, the Engineers Mobility Forum, the Engineering Technologist Mobility Forum and the APEC Engineer Agreement. See www.ieagrements.org.

The process shown in Figure 2 for aspiring Professional Engineering Technicians is similar. The Stage 1 requirement is an accredited National Diploma (ND) in an engineering field. The process of training and experience is similar and assessment for registration is based on evidence of experience and achievement.

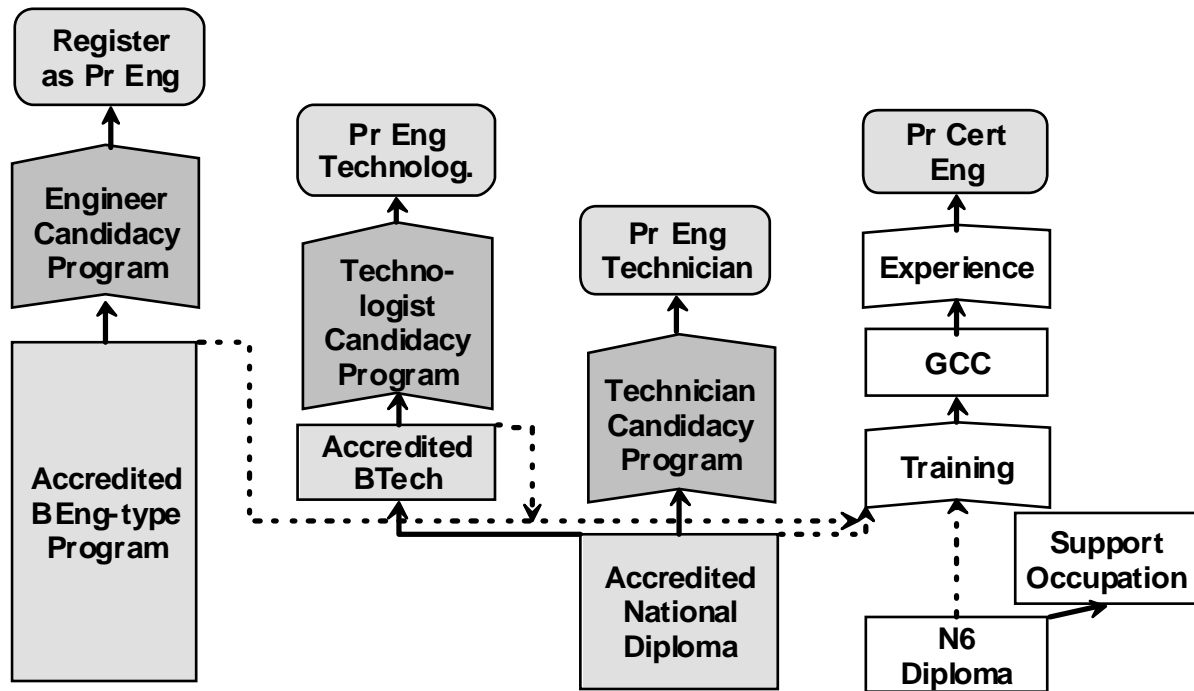


Figure 2: Existing Structure of engineering qualifications and professional designations

The Professional Technologist development path is built on the technician system. The Stage 1 qualification is a one-year accredited BTech in a focussed engineering field following a ND programme. The training and assessment process is similar to that for the technician category. The present Certificated Engineer model, also shown in Figure 2, differs from the pattern of the three generic categories. The model is dictated by the requirement under the Occupational Health and Safety Act and Mine Health and Safety Act that persons who take particular responsibilities under these acts must hold a Government Certificate of Competency (GCC). The GCC is obtained by examination administered by a joint commission set up by the responsible government departments. The examination has two parts: occupation health and safety under the relevant act and engineering practice relevant to the manufacturing or mining industries. Admission to the examination requires one of several academic qualifications indicated by dotted arrows in Figure 2 and prescribed training. The National N-diploma or “N6-diploma” is also shown in Figure 2. This qualification provides a route, typically to

persons who have qualified as artisans, to aspire to a GCC. The N6-diploma also provides education for persons proceeding to engineering support occupations.

Development of the Engineering Qualifications and Professional Designations Framework

A number of factors have driven the ongoing development of engineering professional qualifications and professional designations. First, the EPA explicitly requires that applicants for registration demonstrate their competence against standards. These Stage 2 standards are defined in terms of outcomes that must be demonstrated and the levels of performance, consistent with those recognised internationally (IEA 2005).

Second, the recently promulgated Higher Education Qualifications Framework defines the types of qualifications that may exist in the higher education system. Some adjustments to engineering qualifications are currently under consideration to deal with mismatches between existing and new qualification types. Also, phasing-in of outcomes-based standards for the BTech and ND can now be planned.

Third, the N6 Diploma is being phased out. The HEQF provides for certificate qualifications at NQF Levels 5 and 6. ECSA sees the Level 5 Higher Certificate as a potential enhanced replacement for the N6 diploma.

Fourth, a new model for the Certificated Engineer is under consideration in which the government-conducted GCC examination will fall away and the licencing model under the Occupational Health and Safety and Mine Health and Safety Acts will be based on registration as a Professional Certificated Engineer.

ECSA and the Engineering Standards Generating Body (ESGB) addressed these objectives. While the ideals of the NQF animated the work, conflicts occurred: section 3 details areas of synergy and conflict. To make progress, ECSA and the ESGB conceptualised a framework of engineering qualifications and professional designations that would accommodate present and changing requirements. The Framework has two main organising features: first, the categories of registration, and second, levels of performance, related to the stage of development. The categories are well understood; the level descriptors defined by SAQA were unhelpful. The first problem to be attacked was that of level descriptors (LD).

Level descriptors for Engineering Qualifications and Professional Designations

The NQF has eight levels but lacks suitable descriptors for the higher education and training band. Qualifications with distinguishable exit levels are compressed into the same level, for example the BEng and BTech. A ten-level framework was proposed to address the needs of the higher education sector and is referred to in the promulgated HEQF (DoE 2007). These were readily contextualized for Stage 1 engineering qualifications. Attributes include the level of problem solving, the type and mode of use of knowledge and autonomy of learning.

The HEQF level descriptors are not suited to describing Stage 2 competencies as they lack additional attributes such as the type of engineering activities, specific skills, and level of responsibility taken. SAQA subsequently published for comment proposed level descriptors for a 10-level NQF that better address workplace competencies³ (SAQA 2006a). These level descriptors “provide a broad frame from which the specific and contextualized outcome and assessment criteria for a particular programme can be derived”. The ESGB performed such a contextualisation - ahead of the publication of the SAQA 10-level LDs as it happened.

The groups of competency attributes, A-E, apply with suitable gradation to all categories of registration. Outcomes are written with a common stem across the categories and level differentiators for each category. For example outcome 2 reads as shown in Table 2 for the three generic categories. The stem is “*Design or develop solutions to engineering problems*”. The level discriminators for the three categories are identified by the indicators *complex*, *broadly-defined* and *well defined* supported by detailed definitions for Stage 2 (ECSA 2006a). Definitions are based on the nature of problems, the nature of solutions, the degree to which judgement is required in decision making and the required knowledge base.

Table 2: Method of defining outcomes in Stage 2 competency standards

Category	Common stem ...	Level differentiator	... stem
Engineer	2: Design or develop solutions to	<i>Complex</i>	engineering problems
Technologist		<i>broadly-defined</i>	
Technician		<i>well-defined</i>	
Engineer	4: Manage part or all of one or more	<i>Complex</i>	engineering activities
Technologist		<i>broadly-defined</i>	
Technician		<i>well-defined</i>	

³ These apparently remain in draft form at the time of writing.

A similar approach is used to define outcomes that relate to engineering activities. Outcome 4 shown in Table 2 refers to *complex, broadly-defined* and *well-defined* engineering activities. This shorthand form is backed by definitions of each level of engineering activity in terms of the scope, degree of innovation, resources used, interactions, constraints and risks that professional in each category are expected to be able to handle (ECSA 2006a). This method is consistent with that of the International Engineering Alliance.

The Evolving Framework

The evolving Framework for EQ and PD shown in Figure 3⁴ builds on figure 2 to address the drivers enumerated in Section 2.2. The contextualised ten-level LDs, consistent with the HEQF descriptors, are used for educational qualifications and are marked L5-L8 in the figure. Masters and doctoral qualifications at levels 9 and 10 are outside the scope of this discussion. The Stage 2 Engineering Contextual LDs are used for professional designations. No attempt is made to align the two sets of descriptors because many of the attributes are not common to both sets; this alignment is not essential as the Stage 1 levels define the entry to the candidacy phase and the Stage 2 descriptors its exit level. Levels relevant to Stage 2 are distinguished by S2 and the indicators: complex engineering problems and activities (CEP/A); broadly defined engineering problems and activities (BDEP/A); and well-defined engineering problems and activities (WDEP/A) (ECSA 2006a).

The structure shown in figure 3 responds to the Higher Education Qualification Framework of October 2007. The HEQF has little impact on the engineer pathway as the current BEng degree fits the 480-credit Bachelor-type with exit level 8. Adjustments are required for all other categories. A model for technologist and technician education that has gained support is shown in figure 3.

The present accredited technician education qualification is the National Diploma, conforming to NATED 151 subject requirements and structured with four semesters (“S1 to S4”) of on-campus study and a period (“P1 and P2”) of work-integrated learning (WIL). Analysis of current ND curricula show that the four semesters, typically of about 85 days each, would approach 300 SAQA credits and the WIL to about 60 credits. An outcomes-based qualification was developed with 360 credits total and outcomes pitched at the new

⁴ The process to develop the Framework is ongoing and the form described here must be viewed as work in progress.

level 6 (well-defined engineering problems) as a replacement for the National Diploma (ECSA 2006b). The HEQF level 6 Diploma-type qualification is more demanding, requiring 60 credits at level 7. While the new HEQF diploma-type programme incorporating WIL may remain an accredited qualification, a new benchmark model is proposed. The combination of the Higher Certificate and Advanced Certificate allows a “S1 to S4” replacement to be defined with a minimum of 240 credits and the exit-level outcomes already defined. The WIL component is then transferred to an extended candidacy phase for technicians. Holders of accredited Diplomas that include WIL would omit this component of the candidacy.

The current educational requirement for an Engineering Technologist is a one-year BTech following a national diploma. This model is not accommodated in the HEQF. Two compelling arguments have been raised for change to the technologist educational model. First, international practice indicates the advantages of programmes purpose-designed for the technologist and not built on technician qualifications. Second, consideration of engineering skills-shortages suggests that many more technologists should be produced to play key roles in industry in the application of established technology and the management of technology-based operations. Accommodating the additional numbers effectively and efficiently would be difficult if they have to go through the technician pathway. The proposal is therefore that the accredited qualification for the engineering technologist pathway should be a three-year bachelors degree, exiting at level 7 and having exit-level outcomes consistent with those already developed for the BTech (ECSA 2005a) and international norms (IEA 2005). The candidacy phase may be extended.

The proposed educational requirements for Certificated Engineers of the future are similar to those of the technologist, with specific contextual requirements relating to the core functions of ensuring occupational health and safety and the effective operation of manufacturing or mining plant. Additional articulation paths for persons who started in the technician route are proposed for the Certificated Engineer, for example via the Advanced Diploma.

The proposed set of engineering professional qualifications allows many of the articulation routes envisaged in the HEQF to be exploited. An important feature of the default technician pathway is the possible exit with a Higher Certificate into an engineering support occupation such as engineering draughting. Similarly, persons setting out in support occupations or as artisans could articulate into the technician pathway.

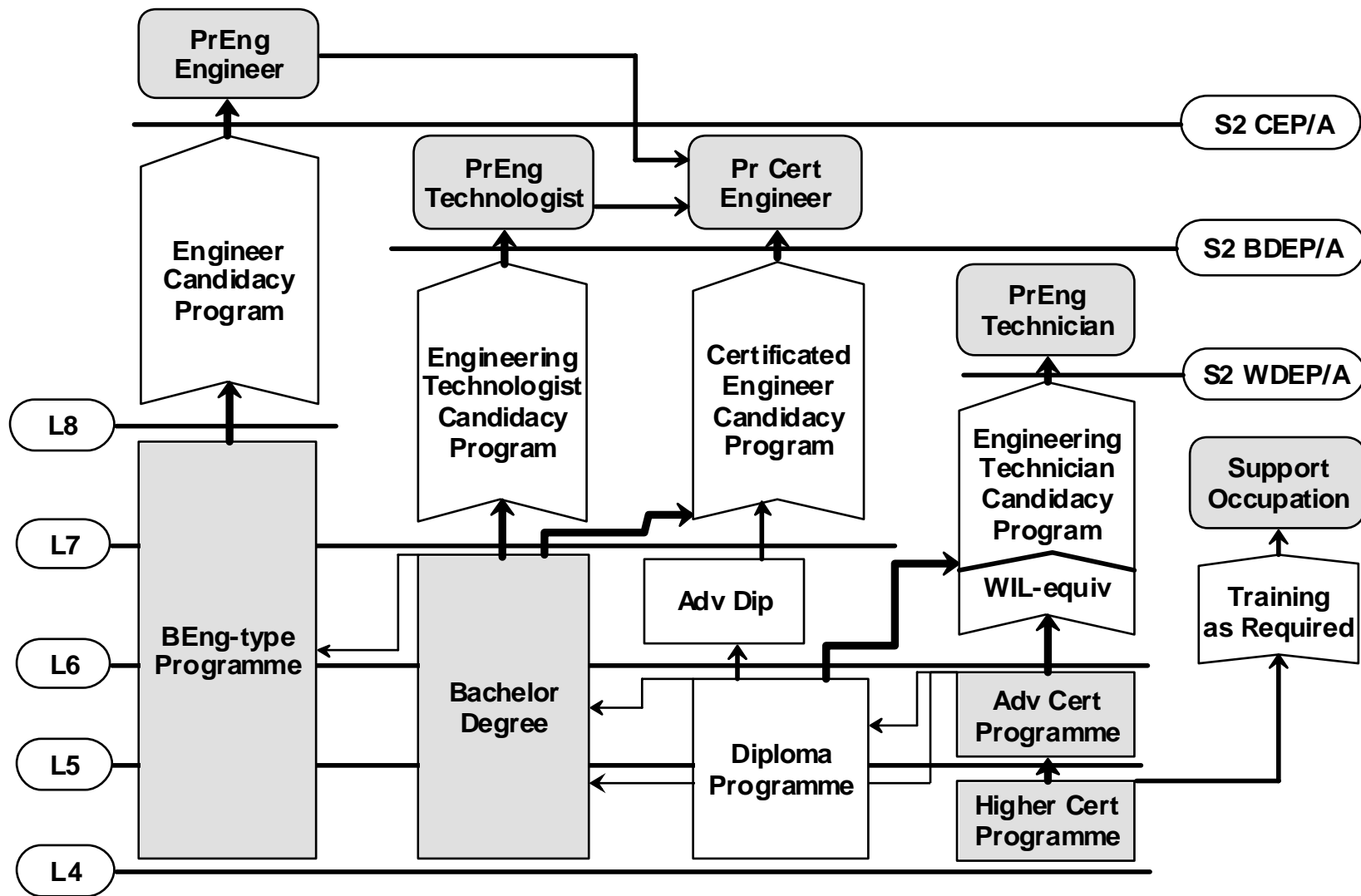


Figure 3: A Target Framework for Engineering Qualifications and Professional Designations

Theme 2: Developing Engineering Qualifications *within* the NQF?

We now examine the extent to which the engineering qualifications and professional designations described in Theme 1 are *within* the NQF. That is, are they in accordance with the objectives, regulations, rules, guidelines and received wisdom of the NQF?

Professional qualifications

SAQA's policy for developing qualifications (SAQA 2000) defines the steps required to generate a qualification for registration on the NQF. Naming, allocation to a band, level, area of practice and determining the total credits pose little problem. Similarly, the purpose of the engineering professional qualifications is well understood. The exit level outcomes are defined next, based on the contextual level descriptors described above. Other elements such as learning assumed to be in place, integrated assessment, registration of assessors, moderation and articulation are completed with little difficulty as common patterns have been established in higher education.

When the standard is registered, SAQA assigns an ETQA. Engineering professional qualifications are regular higher engineering programmes and should be quality assured by the Higher Education Quality Committee (HEQC) of the Council on Higher Education's (CHE). As required by SAQA, the CHE and ECSA entered a Memorandum of Understanding (MoU). Under the MoU, the CHE evaluates new programmes and ECSA quality assures programmes that are in operation and producing graduates. The MoU agrees on the accreditation criteria and process for ongoing programmes. With this arrangement, there is no need for the professional body to register as an ETQA. Quality assurance arrangements are thus established. Engineering professional qualifications are therefore "within" the NQF.

Professional Designations

We now test whether professional designations are "within" the NQF by examining the prescribed standards setting and quality assurance process. The standards process proceeds smoothly through naming, purpose statement and defining exit-level outcomes, level definition and international benchmarking. We use contextual level descriptors and make an arbitrary assignment to the NQF 8-level system. The Stage 1 qualifications define learning assumed to be in place. Ways of reaching the point of assessment to complete the articulation section. The standard will be applied a summative assessment; integrated assessment is therefore not possible. Major difficulties occur when we examine ETQA-related elements.

- The ETQA regulations (RSA 1998) require the ETQA to be a stakeholder body made up of interested organizations. Such body must make use of domain expertise in quality assurance. The ETQA is a lay body, and can only source expertise from the profession.
- Could the profession meet the requirements to be an accredited provider? Some criteria are problematic: the professional body is not required to be registered in terms of “applicable legislation”, nor does it “develop, deliver and evaluate learning programmes...” (RSA 1998). Professions assess but do not train.
- The requirement that the ETQA must register assessors and prescribe and facilitate moderation is appropriate in a mass sector such as SETA-oriented industry education and training. It is invidious that a lay body makes such determinations for a profession.
- Certification of learners by the ETQA conflicts with the profession’s authority and responsibility to register persons and to certify the award of professional designations.
- There are less obvious but potentially serious consequences. A (lay) ETQA could diminish the long-established authority of the profession. The ETQA and its parent, SAQA, risk assuming responsibilities for professional practice standards. The consequence of a professional body not being accredited for its professional assessment and having to stop assessing is unthinkable.

Professional designations cannot be “within” the NQF, other than the core parts of the standards: title, purpose and exit level outcomes.

What are the lessons to be learned?

The qualifier in the title of the paper, “within the NQF” is appropriate to engineering professional qualifications but not for engineering professional designations. The distinction has been made between professional qualifications and professional designations and recommended that the latter should not be treated as qualifications and registered on the NQF (SAQA 2006a, 2006b). We show that ECSA’s experience bears out the wisdom of this conclusion. It is feasible, in the interests of transparency and coherence, to define and even publish (on the authority of the professional body) the core of the competency standards: the title, purpose, outcomes, level descriptors and contextual requirements. Insurmountable difficulty arises when further requirements for registered qualifications are prescribed: the identification of an ETQA, integrated assessment, registration of assessors and prescribed moderation arrangements. These considerations are not lost: the statutory profession takes care of issues where the ETQA arrangements would fail including ensuring that assessors are qualified, moderation, certification and that guidelines for training and mentoring.

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