ENSURING THE
EXPERTISE TO GROW
SOUTH AFRICA

Guide to the Competency Standards for Registration in Professional Categories

R-08-CS-GUIDE-PE/PT/PN

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ECSA

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DEFINITIONS

Continuing Professional Development: The systematic maintenance, improvement and broadening of knowledge and skills, and the development of personal qualities necessary for the execution of professional and engineering duties throughout an engineering practitioner's career.

Engineering problem: A problematic situation that is amenable to analysis and solution using engineering science and methods.

Engineering science: A body of knowledge based on the natural sciences and using a mathematical formulation where necessary that extends knowledge and develops models and methods to support its application, to solve problems and to provide the knowledge base for engineering specialisations.

Integrated performance: The overall satisfactory outcome of an activity, which requires several outcomes to be satisfactorily attained. For example, a design will require analysis, synthesis, analysis of impacts, checking of regulatory conformance and judgement in decisions.

Level descriptor: A measure of performance demands at which outcomes must be demonstrated.

Outcome: A statement of the performance criteria that a person must demonstrate to be judged competent at the professional level.

Practice area: A generally recognised or distinctive area of knowledge and expertise developed by an engineering practitioner through the path of education, training and experience followed.

ABBREVIATIONS

BDEA	broadly defined engineering activities
CEA	complex engineering activities
CPD	Continuing Professional Development
DoR	Degree of responsibility
ECSA	Engineering Council of South Africa
IPD	Initial Professional Development
PD	Professional Development
PE	Professional Engineer
PN	Professional Engineering Technician
PT	Professional Engineering Technologist
WDEA	well-defined engineering activities

BACKGROUND

The documents that define the Engineering Council of South Africa (ECSA) system for registration in professional categories are shown in Figure 1 below. The grey text box indicates the current document.

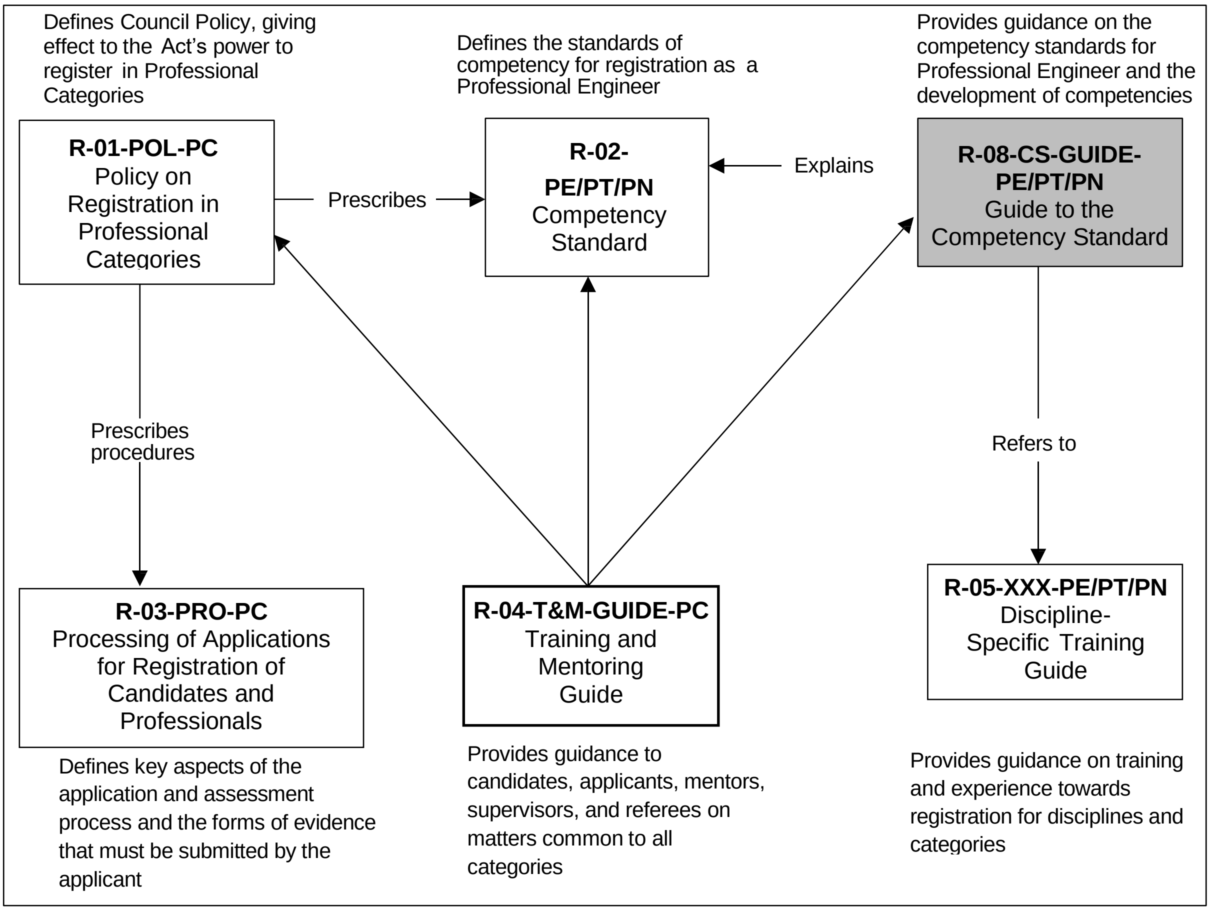

Figure 1: Documents defining the ECSA registration system

1. PURPOSE OF THIS DOCUMENT

This guide, **R-08-CS-GUIDE-PE/PT/PN**, amplifies the general training and mentoring guide (document **R-04-T&M-GUIDE-PC**), concentrating on an understanding of the competency standards for Professional Engineers, Professional Engineering Technologists and Professional Engineering Technicians that are defined in document **R-02-STA-PE/PT/PN**. This guide (document **R-08-CS-GUIDE-PE/PT/PN**) can be used to determine if an applicant is ready for professional registration. In addition, this guide/document indicates ways of developing the requisite competencies and how the competencies can be demonstrated through engineering work. This guide may, in turn, be supplemented by the *Discipline-Specific Training Guide*, document **R-05-XXX-PE/PT/PN**, if available for the applicant's discipline.

The intended audience of this guide is applicants undergoing training towards professional registration and their mentors and supervisors. This document is also an important document for persons registered as Professional Engineers / Professional Engineering Technologists / Professional Engineering Technicians who serve as assessors, moderators and reviewers of candidates or applicants applying for registration.

2. INTRODUCTION TO COMPETENCY, STANDARDS AND PERFORMANCE

What is the competency of a Professional Engineer / Professional Engineering Technologist / Professional Engineering Technician? In general, *competence* is defined as possession of the necessary *knowledge*, *skills* and *attitudes* to perform the activities within the professional category to the standards expected in independent employment or practice.

The knowledge component of competency consists of knowledge from the engineering education process as well as knowledge that is subsequently acquired during specialised engineering-related activities both in the work environment and from Continuing Professional Development (CPD). The skills and attitude components are defined by a set of assessable outcomes.

The ECSA Competency Standard, document **R-02-STA-PE/PT/PN**, provides the formal definition of the competence that must be demonstrated to be registered as a Professional Engineer, Professional Engineering Technologist and/or Professional Engineering Technician. The Competency standard applies to all engineering disciplines and specialities. Contexts and functions in which competency may be developed and the outcomes demonstrated may be described in the applicable Discipline-specific Training Guide **R-05-XXX-PE/PT/PN**.

According to the Competency Standard, document **R-02-STA-PE/PT/PN**, the following competencies must be demonstrated:

- **Within complex** engineering activities for Professional Engineer

- **Within broadly defined** engineering activities for Professional Engineering Technologist
- **Within well-defined** engineering activities for Professional Engineering Technician
- ***By*** the *integrated performance* of the outcomes
- ***At*** the *level defined* for each outcome.

This guide, document **R-08-CS-GUIDE-PE/PT/PN**, enlarges on the outcomes, the level of performance and the integrated performance required of an applicant for registration as a Professional Engineer, Professional Engineering Technologist and/or Professional Engineering Technician.

3. OUTCOMES FOR PROFESSIONAL REGISTRATION

Candidates/applicants must demonstrate all 11 outcomes to be considered for professional registration. The following section should be consulted by candidates/applicants and used as a rubric to determine if they are receiving the necessary exposure. Assessors, moderators and reviewers specifically utilise these outcomes to evaluate candidates' /applicants' applications for professional registration.

3.1 Overview of outcomes

The outcomes required for professional registration as outlined in the Competency Standard, document **R-02-STA-PE/PT/PN**, are summarised in Table 1 below in a nested Group A–E configuration. In addition to Table 1, applicants need to further refer to the detailed competency indicators for each category that are stipulated in Competency Standard for Registration **R-02-STA-PE/PT/PN**.

Table 1: Overview of outcomes

Group	Outcome	Description professional engineer	Description professional technologist	Description professional technician
Group A Knowledge-based engineering	1	Define, investigate, and analyse *complex engineering problems*.	Define, investigate, and analyse *broadly defined engineering problems*.	Define, investigate, and analyse *well-defined engineering problems.*

Group	Outcome	Description professional engineer	Description professional technologist	Description professional technician
problem-solving	2	Design or develop solutions to *complex engineering problems.*	Design or develop solutions *broadly defined engineering problems.*	Design or develop solutions to *well-defined engineering problems.*
	3	Comprehend and apply advanced knowledge of the widely applied principles that underpin good engineering practice, specialist knowledge and knowledge specific to the jurisdiction and local conditions jurisdiction in which the candidate or applicant practises.	Comprehend and apply knowledge embodied in widely accepted engineering principles, practices, procedures, processes, systems or methodologies specific to the jurisdiction in which the candidate or applicant practises.	Comprehend and apply the knowledge embodied in established engineering practices and the knowledge specific to the jurisdiction in which the candidate or applicant practise.
Group B Managing engineering activities	4	Manage part or all of one or more *complex engineering activities.*	Manage part or all of one or more *broadly defined engineering activities*.	Manage part or all of one or more *well-defined engineering activities.*
	5	Communicate clearly with others in the course of the candidate's or applicant's engineering activities.	Communicate clearly with others in the course of the candidate's or applicant's engineering activities.	Communicate clearly with others in the course of the candidate's or applicant's engineering activities.
Group C Risk and impact mitigation	6	Recognise and address the reasonably foreseeable social, cultural, environmental and sustainability effects of *complex engineering activities (CEA).*	Recognise and address the reasonably foreseeable social, cultural, environmental and sustainability effects of *broadly defined engineering activities (BDEA).*	Recognise the reasonably foreseeable social, cultural, environmental and sustainability effects of *well-defined engineering activities (WDEA).*
		Meet all legal and regulatory	Meet all legal and regulatory requirements	Meet all legal and regulatory

Group	Outcome	Description professional engineer	Description professional technologist	Description professional technician
	7	requirements and protect the health and safety of persons and adhere to sustainable practices during the candidate's or applicant's *complex engineering activities (CEA)*.	and protect the health and safety of persons and adhere to sustainable practices during the candidate's or applicant's *broadly defined engineering activities (BDEA).*	requirements and protect the health and safety of persons and adhere to sustainable practices during the candidate's or applicant's *well-defined engineering activities (WDEA)*.
Group D Act ethically, exercising judgement and taking responsibility	8	Conduct engineering activities ethically	Conduct engineering activities ethically	Conduct engineering activities ethically
	9	Exercise sound judgement in the course of *complex engineering activities (CEA)*.	Exercise sound judgement in the course of *broadly defined engineering activities (BDEA).*	Exercise sound judgement in the course of *well-defined engineering activities (WDEA)*.
	10	Be responsible for making decisions regarding part of or all of the *complex engineering activities.*	Be responsible for making decisions regarding part of or all of the *broadly defined engineering activities.*	Be responsible for making decisions on part of or all of the *well-defined engineering activities.*
Group E Professional development	11	Undertake professional development that is sufficient to maintain and extend the candidate's or applicant's competence.	Undertake professional development that is sufficient to maintain and extend the candidate's or applicant's competence.	Undertake sufficient professional development activities to maintain and extend the candidate's or applicant's competence.

As described in the Competency Standard, document **R-02-STA-PE/PT/PN** and depicted in ***Table 1*** above, the outcomes do not stand alone as performance of the outcomes must be integrated successfully. Competent engineering work invariably requires the simultaneous performance of several of the actions embodied in the outcomes.

Outcomes 1, 2, 4 and 5 capture the essential functions of Professional Engineers, Professional Engineering Technologists and/or Professional Engineering Technicians, which are all supported by communication and involve in analysing and solving problems as well as managing processes, projects and operations to deliver results. To perform these four core functions, Professional Engineers, Professional Engineering Technologists and/or Professional Engineering Technicians rely on fundamental and specialised engineering knowledge and knowledge of the context in which the work takes place.

Outcome 3 reflects the importance of engineering knowledge: This is the essence of engineering work. While solving problems and managing processes, Professional Engineers, Professional Engineering Technologists and/or Professional Engineering Technicians must be able to identify and deal with the impacts of the solutions and the applicable regulatory requirements as reflected in Group C (i.e., Outcomes 6 and 7).

Several attributes are not necessarily taught or necessarily part of the education component but are essential at a personal level; Professional Engineers, Professional Engineering Technologists and/ or Professional Engineering Technicians must act ethically, exercise judgement and take responsibility as reflected in Group D (i.e., Outcomes 8, 9, 10).

Outcome 11, shown as an underpinning layer to all the other outcomes, emphasises the need to develop professionally, that is, to increase knowledge and to gain the required competencies for the effective performance of engineering work.

An alternative visualisation of the set of 11 outcomes is depicted in **Figure 2** below. Problem-solving (analysis and synthesis) is seen in the central position, with competencies represented by other outcomes as supporting roles.

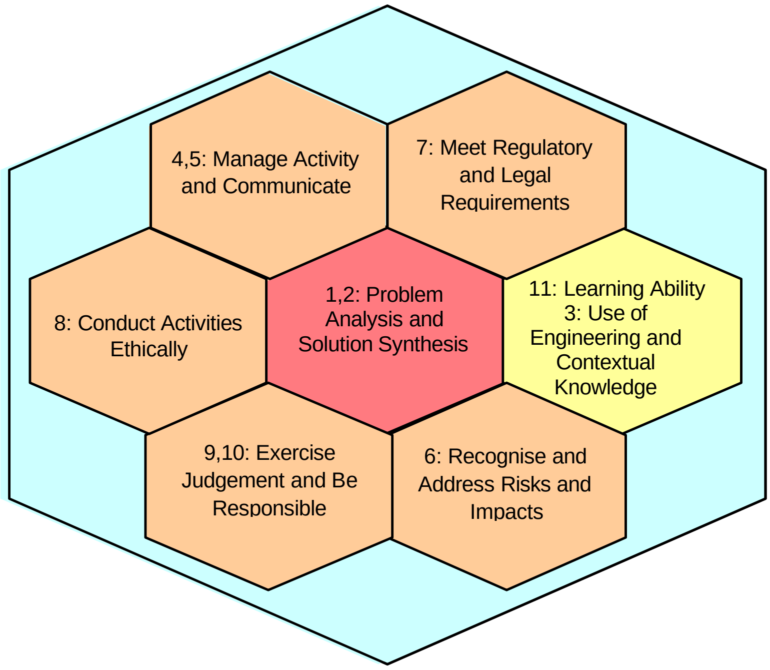

Figure 2: Summary of the 11 outcomes:

3.2 Demonstrating the achievement of outcomes for professional registration

All the outcomes defined in document **R-02-STA-PE/PT/PN** and summarised in **Table** *1* of this document may arise from work demonstrating varying levels of demand and responsibility. At what level must a person demonstrate the defined outcomes to be declared competent to register as a Professional Engineer, Professional Engineering Technologist and/or Professional Engineering Technician? Two level-descriptors for the DoR (Degree of Responsibility) defining phrases are presented as having specific meanings in the Competency Standard document, **R-02-STA-PE/PT/PN** as follows for a:

Professional Engineer:

- A set of level descriptors for a *complex engineering* problem.
- The level descriptors that allow an engineering activity to be classified within *complex engineering* activities.

Professional Engineering Technologist:

- A set of level descriptors for a *broadly defined engineering problem*.
- The level descriptors that allow engineering activity to be classified within *broadly defined engineering activities*.

Professional Engineering Technician:

- A set of level descriptors for a *well-defined engineering problem*.
- The level descriptors that allow an engineering activity to be classified within *well-defined engineering activities*.

The DoR has level of descriptors per nature of work undertaken at different levels of work experience for the applicant (i.e., Levels A–E), as defined in the *Training and Mentoring Guide*, document **R-04-T&M-GUIDE-PC**. These are used to measure the progression of the applicant's competency as illustrated in Table 2 below. The applicant's competency for registration as a Professional Engineer, Professional Engineering Technologist and/or Professional Engineering Technician is expected to be at Level E for DoR in regard to solving complex engineering problems or broadly defined engineering problems and/or well defined engineering problems, carrying out the activities for each outcome.

Table 2: **The nature of work and summary of DoR defined in document R-04-T&M-GUIDE-PC**

DoR	Nature of work	Responsibility	Level of support
A: Being Exposed	Undergoes induction, observes processes, work of competent practitioners	No responsibility, accept to pay attention	Mentor explains challenges and forms of solution
B Assisting	Performs specific processes under close supervision	Limited responsibility for work output	Supervisor/Mentor coaches, offers feedback
C Participating	Performs specific processes as directed with limited supervision	Full responsibility for supervised work	Supervisor progressively reduces support, but monitors outputs
D Contributing	Performs specific work with detailed approval of work outputs	Full responsibility to supervisor for quality of work	Candidate articulates own reasoning and compares it with that of supervisor
E Performing	Works in a team without supervision, recommends work	Level of responsibility to supervisor is	Candidate takes on problem solving

DoR	Nature of work	Responsibility	Level of support
	outputs, responsible but not accountable	appropriate to a registered person	without support; at most limited guidance

3.3 Defining engineering activities

The Competency Standard, document **R-02-STA-PE/PT/PN**, takes a broad view of defining engineering activities, listing several possible functions such as design; planning; investigation and problem resolution; improvement of materials, components, systems and processes; implementation, construction, manufacture and engineering operations; maintenance; project management; research; development; and commercialisation.

The Discipline-specific Training Guideline **R-05-XXX-PE/PT/PN** should be consulted for the types of activities that a candidate needs to perform to demonstrate competence.

In summary, evidence of competent performance has two essential requirements:

- Capability to perform a number of defined *actions* must be demonstrated.
- Performance must be at or exceed a *specified level of demand*.

The defined actions are the outcomes, and the level of performance is defined by the specification for the demands of the engineering activities and the nature of problem-solving. In a professional field, evidence of competent performance is obtained from the competent performance of substantial engineering tasks by the person being assessed. Typical tasks provide evidence of several outcomes, and assessment of activities / knowledge is holistic.

The *Processing of Applications for Registration of Candidates and Professionals*, document **R-03-PRO-PC**, identifies areas of change from the training-based requirements to output-based competency standards and the accompanying changes in the preparation of applications and assessments of competency.

3.3.1 Engineering activities for a Professional Engineer:

Group A: Knowledge-based engineering problem-solving

As described in *Table 1* of this document, Group A consists of three outcomes:

- **Outcome 1 –** Define, investigate, and analyses complex engineering problems.

- **Outcome 2 –** Design or develop solutions to complex engineering problems.
- **Outcome 3 –** Comprehend and apply advanced knowledge of the widely applied principles underpinning good engineering practice, specialist knowledge and knowledge specific to the jurisdiction and local conditions.

Outcome 1

What is engineering problem-solving?

Problem-solving is a process carried out by individuals or teams to bring about a change from a given state to a desired state by means of multistep or multipath activities with barriers that must be overcome through using knowledge and abilities and taking situational requirements into account. Engineering problem-solving relies on the fundamental engineering sciences and specialised engineering knowledge. Proficiency in solving engineering problems at the level described as *complex* is a characteristic of the competency of a Professional Engineer.

Problem-solving is the common thread that runs through engineering activities and is required in many engineering fields including design, planning, implementing and constructing, operating engineering systems, infrastructure and plants. Competency in problem-solving has two phases, analysis and solution synthesis, as captured in Outcomes 1 and 2 of document **R-02-STA-PE/PT/PN**. Because engineering problem-solving is knowledge-based, Outcome 3 is grouped with Outcomes 1 and 2. However, Outcome 3 also supports other outcomes in line with the notion of integrated performance as described in document **R-02-STA-PE/PT/PN**.

Complex engineering problem-solving is perhaps the best starting point for an applicant to determine the level at which they are working. Complex engineering problem-solving must be demonstrated for an applicant to be considered for professional registration. Applicants who are unsuccessful in their application are often either not performing at the required level of complexity of problem-solving or have not conveyed it appropriately in the reports and in the review process.

An applicant should refer to the suggested test for a complex engineering problem as recorded in document **R-02-STA-PE/PT/PN**. The test is based on the four logical steps illustrated in

Table 3 below. If there is one or more affirmative answers at each step, the problem is classified as a complex engineering problem.

Table 3 Test for a complex engineering problem

Step	Main question	Criteria
Step 1 Identify the engineering problem	Is the problem an engineering problem?	a) Does solving the problem require in-depth fundamental and specialised engineering knowledge?
Step 2 Establish the level of complexity of the initial problem state	What is the nature of the problem? Does it have *one or more* of the characteristics b, c and d?	b) The problem is ill-posed, under- or over specified and requires identification and refinement.
		c) The problem is a high-level problem and includes component parts or sub-problems.
		d) The problem is unfamiliar or involves infrequently encountered issues.
Step 3 Determine the complexity of the solution path from the initial state	What is encountered in the solution process? Do the solutions have *one or more* of the characteristics e, f, g and h?	e) The solutions are not obvious and require originality or analysis based on fundamentals.
		f) The solutions are outside the scope of standards and codes.
		g) The solutions require information from a variety of sources that are complex, abstract or incomplete.
		h) The solutions involve wide-ranging or conflicting issues such as technical and engineering issues and interested or affected parties.
Step 4 Determine the level of decision-making required and potential consequences	What is involved in the decision-making while solving the problem and evaluating the solution? Does it have *one or more* of the characteristics i and j?	i) Decisions require judgement in decision-making in uncertain contexts.
		j) Decisions have significant consequences in a range of contexts.

Outcome 2

How will I know when I am performing adequately at problem-solving?

At the endpoint of training, applicants must demonstrate these three competencies through their work. The starting point for training is the level of problem-solving ability of the new graduate. The applicant is expected to produce the same level of problem-solving but in a work environment rather than within academia. The applicant must develop problem-solving abilities in an environment in which the consequences of engineering decisions and actions are significant.

At graduation, the candidate's knowledge centres on the scientific basis of engineering, engineering technologies, some contextual knowledge and some specialist knowledge. During preparation for registration, knowledge must develop in the applicant's practice area and be relevant to the context in which the applicant practises.

Mentors, supervisors and applicants must plan the progression of tasks and responsibility to ensure the development of these competencies. They are advised to use suitable planning, recording and assessment tools and feedback sessions. The applicant's progress should be evaluated against each outcome using the DoR scale in ***Table*** *2* of document **R-04-T&M-GUIDE-PC**. It should be noted that the same body of work may enable development of competencies in other groups.

The strategy for developing problem-solving competence to the level required in the workplace and the DoR is illustrated in *Table 2* of this document. The following steps are examples of developing required competencies:

- Initially, the candidate/applicant assists experienced engineering personnel in their problem analysis and solution activities, receiving detailed guidance and continuous monitoring.
- The candidate/applicant then progresses to contribute individually and as a team member in the solution of engineering problems.
- Finally, the candidate/applicant must achieve Level E DoR, performing individually and as a team member, to solve problems. In this last phase, the candidate/applicant must perform over the entire problem lifecycle.

The applicant should be given the opportunity to experience complex problem-solving in contexts such as design, investigation, planning, and process and product improvement. The applicant should be encouraged to apply first principles to complex problems in order to develop and apply specialist and contextual knowledge.

Considering the problem of assessing a person's performance against Outcomes 1 and 2, it is necessary to determine if the person performs a creative, systematic analysis of problems at the required level and if the person works systematically to synthesise a solution to the problems.

An example of a schema for the systematic analysis is presented below. The candidate:

- identifies and formulates the problem, which leads to an agreed definition of the problem to be addressed
- collects, organises and evaluates information
- uses conceptualisation, abstraction and modelling
- identifies and justifies assumptions, limitations, constraints and premises
- uses both mathematical and non-mathematical analytical methods
- evaluates the results of the analysis, using judgement
- expresses understanding of the results emerging from the analysis.

A similar schema would apply to the synthesis phase. The applicant:

- analyses the requirements for the design/planning/solution and draws up a detailed requirements specification
- synthesises a range of potential solutions to the problem or a range of approaches to developing a solution that is consistent with assumptions, premises, limitations and constraints
- evaluates the potential approaches against the requirements and includes cost and impacts outside the requirements
- presents reasoned arguments and a proposal for the preferred option
- fully develops the design of the selected option
- evaluates the resulting solution
- produces design documentation for implementation.

What type of problem could be offered to demonstrate problem-solving ability?

Many types of problems would suffice; the problem may be a design requirement, an applied research and development requirement or a problematic situation in an existing component, system or process. The solution may be the design of a component, system or process or a recommendation of the remedy for the problematic situation.

The level of the problem analysed must be gauged by the test described above to determine its suitability for presentation as evidence of competence. Problem-solving is the core activity of engineering. A wide range of engineering functions are either specific manifestations of problem-solving or are functions that rely on problem-solving at different levels. Some examples follow:

- Design is the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes. Design involves the transformation of an initial requirement to produce documented instructions on how to realise the end product. In determining a solution, barriers must be overcome. A design assignment, therefore, is an engineering problem and involves sub-problems that must be addressed.
- Product or process improvement also involves problem-solving. Frequently, an existing piece of infrastructure, plant or process is in need of improvement. The proper process is to analyse the exiting state and define the desired final state, and this process must be developed. Again, the investigation is a problem-solving activity, as is the solution synthesis phase

Problem-solving based on engineering knowledge is at the centres of other engineering activities such as planning, research, development and technology transfer, quality assurance, risk analysis, domain-specific project management, managing engineering processes, safe work practices, environmental protection, sustainability analysis and systems engineering.

Outcome 3

How will I display my application of engineering and contextual knowledge?

All engineering activities, particularly problem-solving, rely on a body of knowledge. The statement of Outcome 3 recognises the three components that comprise the knowledge of a Professional Engineer:

- Knowledge is rooted in principles (generally first principles) of general laws of the natural and engineering sciences and the principles of good engineering practice.
- It is recognised that individual Professional Engineers develop specialised knowledge that may be in a generally recognised area or may be a particular combination of topics.
- Knowledge specific to the environment in which the person practises is essential. It includes knowledge about the society, economy, regulatory system and physical environment in which the person practises engineering.

Engineering knowledge is too diverse to allow a detailed specification for every discipline, sub-discipline or practice area. Rather, it is recognised that each engineering practitioner develops a practice area. The Discipline-specific Training Guideline, document **R-05-XXX-PE/PT/PN**, may be consulted on this topic. For example, the practice area may be a commonly understood area such as structural engineering or power distribution, or it may be a particular blend emanating from the individual's experience. The engineering knowledge requirements in document **R-02-STA-PE/PT/PN** are, therefore, stated in generic terms.

For the Professional Engineer, the engineering fundamentals acquired in an accredited undergraduate programme form the base for specialist knowledge, and the Professional Engineer must be capable of first-principles analysis. Fundamental knowledge may be used explicitly or tacitly.

Professional Engineers invariably work in teams with specialists, engineering role-players, contractors and other parties from other engineering disciplines and professions. It is, therefore, essential to have a working knowledge of the discipline and the areas in which interaction is required. The applicant needs to be aware that certain engineering disciplines may require more diverse cross-discipline interaction and knowledge. However, this depends on the environment and the level at which the engineer is performing the work.

Engineering work does not occur in isolation, and knowledge of the health and safety, environmental, contractual, quality and risk regulatory requirements is essential. The application of engineering knowledge as an outcome is normally demonstrated during design, investigation or operations. The applicant typically:

- displays mastery in the understanding of engineering principles, practices and technologies in the practice area
- applies general and underpinning engineering knowledge to support analysis and to provide insight
- uses an analytical approach based on fundamentals and first principles in building models as required
- displays working knowledge of areas that interact with the practice area
- applies related financial, statutory, safety and management knowledge.

Group B: Managing engineering activities

Groups B, C and D reflect the competencies linked to problem-solving (Group A) and are essential to engineering activities at the professional level. For example, considering impacts is an important stage in the solution of a problem. Similarly, engineering operations also have impacts that must be assessed and managed.

As described in Table 1 of this document, Group B consists of two outcomes:

- **Outcome 4** – Manage part or all of one or more complex engineering activities.
- **Outcome 5** – Communicate clearly with others in the course of Professional Engineer's engineering activities.

Outcome 4

What are engineering managing competencies?

Competent Professional Engineers must not only perform technical functions but must also manage engineering activities. Two statements of management competency are presented in Group B in document **R-02-STA-PE/PT/PN**. Competency to manage *complex engineering* *activities* must be demonstrated. Linked with management is the ability to communicate with those involved in the engineering activities.

Engineering management can be defined as the application of the generic management functions of planning, organising, leading and controlling together with engineering knowledge in contexts that include the management of projects, construction, operations, maintenance, quality, risk, change and business. The level of experience in engineering management is of necessity limited at the stage of applying for registration as a Professional Engineer. However, the applicant must take on the requisite responsibility to demonstrate competency under the guidance of suitably competent persons, as described in document **R-04-T&M-GUIDE-PC**.

Engineering management is more than project management. In most cases, project management is supportive of technical engineering activity but does not demonstrate the acceptable level of performance at the required degree of responsibility.

Demonstration of the Competency Standard in document **R-02-STA-PE/PT/PN** provides a test of whether a given engineering activity is classed as a complex engineering activity. The test for complex engineering activity is summarised in this document in Table 2. The test is applied to the activity itself to determine the complexity of its scope and operating environment, resource intensiveness, and severity of constraints, risks and consequences. This test is not independent of the test for complex problem-solving; most of the factors are those that give rise to barriers in the problem-solving process and render the problem complex.

The definition of the required level of activity in document **R-02-STA-PE/PT/PN** does not imply that applicants in every category must work at the stated level all the time. Rather, applicants in each category must demonstrate the ability to practise at the required level. Similarly, at the culmination of training, applicants must be able to demonstrate that they are capable of performing the required actions at the required levels through physically carrying out the actions in the work situation.

The progression of levels of engineering work and the DoR defined in document **R-04-T&M-GUIDE-PC** are presented below.

Level A	Exposure
Level B	Assisting
Level C	Participating
Level D	Contributing
Level E	Performing

The applicant's various phase activities assist in developing the ability to plan, organise, lead and control. The applicant must be able to perform these functions alone and in a team. Conducting engineering work alone or in a team requires planning and organising to attain the required technical outcomes. Team participation and contribution as a team member and as a leader give the opportunity to demonstrate leadership and the ability to control on a limited scale.

Outcome 5

How do I know when I am managing and communicating at the required level?

Technical communication at a level that supports analysis, synthesis and implementation of solutions is an inherent part of engineering work. The applicant needs the opportunity to communicate orally and in writing not only technical matters but also financial, social, cultural, environmental or political aspects of engineering activity.

In fulfilling Outcome 5, the applicant is expected to display personal and work process management abilities:

- Manage self
- Work effectively in a team environment
- Manage people, work priorities, work processes and resources
- Establish and maintain professional and business relationships; effective communication can be demonstrated by the ability to write clear, concise and effective reports that are technically, legally and editorially correct using a structure and style that meets communication objectives and user/audience requirements..

Effective communication can be demonstrated by:

- writing clear, concise, effective reports that are technically, legally and editorially correct using a structure and style that meet communication objectives and user/audience requirements
- reading and evaluating technical and legal matter relevant to the function of the Professional Engineer
- receiving instructions and ensuring correct interpretation
- issuing clear instructions to subordinates using appropriate language and communication aids, ensuring that language and other communication barriers are overcome
- making oral presentations using structure, style, language, visual aids and supporting documents appropriate to the audience and purpose.

This outcome will be evaluated at the following two stages:

- The applicant's written application for registration.
- The review process in which the applicant is required to make a presentation and answer questions during the professional review.

Group C: Risk and impact mitigation

As described in Table 1 of this document, Group C consists of two outcomes:

- **Outcome 6** – Recognise and address the reasonably foreseeable social, cultural and environmental effects of *broadly defined engineering activities.*
- **Outcome 7 –** Meet all legal and regulatory requirements and protect the health and safety.

Outcome 6

How do I know when I am able to analyse and manage the impacts, benefits and consequences of engineering activities?

Engineering activities deliver benefits to society and the economy in the form of infrastructure, services and goods. Engineering involves harnessing or controlling natural forces or using and controlling complex information. The actions inherent in engineering activities have accompanying risks. These risks must be mitigated to a level that is acceptable to the affected parties. The management of risk accompanying engineering activity is the very rationale for the regulation of the profession. Some risks are well known and understood and the means of addressing them may be embodied in regulation, for example, pressure vessel design. Other situations may not occur frequently or may occur for the first time with the application of new technology and in consequence may not be regulated. Certain risks may have objective technical measures while others are subject to the judgement of individuals and communities. Some risks may be ethical (Outcome 8 in Group D). The ability to assess and deal with all prevailing risks is integral to the competency of a Professional Engineer: The Professional Engineer is expected to be able to identify and deal with the wide-ranging risks associated with engineering work.

The applicant should be given the opportunity to study, analyse and recommend measures for

- social/cultural impacts
- community/political considerations
- environmental impact
- sustainability analysis
- regulatory conditions
- potential ethical dilemmas.

To demonstrate competency in *impact analysis and mitigation*, the following must be accomplished:

- Identify interested and affected parties and their expectations.
- Identify interactions between technical considerations and sociocultural and environmental factors.
- Identify environmental impacts of the engineering activity.
- Identify sustainability issues.
- Propose and evaluate measures to mitigate negative effects of engineering activity.
- Communicate with stakeholders.

Outcome 7

How do I know when I have met all the legal and regulatory requirements in the course of my engineering activities?

Outcome 7 is concerned with explicitly regulated aspects of engineering practice and more general legislation that may apply. Each applicant should ascertain the applicable legislation in one's work environment. Appendix A of this document and the Discipline-specific Guideline, document **R-05-XXX**, lists recommended (but not exhaustive) material that should be consulted, including relevant legislation.

Of particular importance is occupational health and safety legislation. Two principal Acts are applicable in the South African context:

- Occupational Health and Safety Act, 85 of 1993, as amended, and associated regulations.
- Mine Health and Safety Act, . 29 of 1996, as amended.

While certificated engineers have a specific responsibility under these Acts. All Professional Engineers must be cognisant of the Acts and comply with their provisions.

To demonstrate competency *in regulatory aspects*, the applicant must:

- identify applicable legal, regulatory and health and safety requirements for the engineering activity
- identify risk and apply defined and widely accepted risk-management strategies
- select safe and sustainable materials, components, processes and systems.

Group D: Act ethically, exercising judgement and taking responsibility

As described in Table 1 of this document**,** Group D consists of three outcomes:

- **Outcome 8 –** Conduct engineering activities ethically.
- **Outcome 9 –** Exercise sound judgement in the course of complex engineering activities.
- **Outcome 10** – Be responsible for making decisions on part or all of complex engineering activities.

Professional Engineers must make technical and managerial decisions regarding the risks that arise from their activity. Three outcomes in Group D are concerned with competencies exercised at a personal level.

Outcome 8

How do I know when I have developed the competency to conduct engineering activities ethically?

Outcome 8 simply states: Conduct engineering activities ethically. The baseline for ethical behaviour is the ECSA Code of Conduct, which covers the need to practise ethically and within one's area of competency, to work with integrity, to respect the public's interest and the environment and to uphold the dignity of the profession, including one's relationship with fellow professionals. The ECSA Code of Conduct also contains a section on administrative matters that relate to ethical practice. The applicant must study the ECSA Code of Conduct and be aware of its implications in situations that arise in engineering work.

As in other professions and business situations, ethical problems arise in engineering activity. These may relate to business practices, inducements or an unregulated impact, for example, the use of a rare and unsustainable material for a solution that will be required well into the future. The Professional Engineer must be capable of detecting, analysing and handling ethical dilemmas and problems that arise in the course of engineering activity. This is a non-negotiable aspect of the Code of Conduct, and the Professional Engineer must handle any ethical problems that arise

An applicant who is capable of handling ethical issues adopts a systematic approach to resolve ethical issues, which is typified by:

- identifying the central ethical problem
- identifying affected parties and their interests
- searching for possible solutions to the dilemma
- evaluating each solution using the interests of those involved and according suitable priority
- selecting and justifying the solution that most appropriately resolves the dilemma.

Outcome 9

How do I know when I have exercised sound judgement in the course of broadly defined activities?

The Professional Engineer is expected to make decisions in situations where the information to underpin the decision may be highly complex; that is, it has many parts with a myriad of interactions, or it may be incomplete. Such decision-making requires due care by the Professional Engineer and may be informed by experience. The Professional Engineer, therefore, must have the ability to think of many matters at once and address their interdependence, their relative importance and their consequences. This process is known as exercising *judgement* within *complex engineering activities* or exercising equal judgement in the solution of *complex engineering problems.*

Firstly, applicants considering the Training and Mentoring Guide, document **R-04-T&M-GUIDE-PC**, should be given the opportunity and be challenged to make decisions when full information is not available to:

- use engineering judgement
- take due care that the outputs and impacts of an assignment are addressed
- self-assess their competence from time to time.

All the above should be done under the supervision and guidance of a suitably qualified person as described in document **R-04-T&M-GUIDE-PC**.

Secondly, the indication that an applicant exhibits engineering judgement is typically demonstrated by the following:

- Considering several factors, some of which may be ill-defined or unknown.
- Considering the interdependence, interactions and relative importance of factors.
- Foreseeing consequences of actions.
- Evaluating a situation in the absence of full evidence.
- Drawing on experience and knowledge.

Outcome 10

How do I know when I have taken responsibility for broadly defined engineering activities?

Engineers are accorded professional status in society by virtue of their competence, the fact that the profession self-regulates and because professionals are accountable for their actions. The person registering as a Professional Engineer must therefore understand the obligation to be responsible and to have experience in making decisions, which if wrong, could have adverse consequences. Subject to the limitations of taking responsibility as a candidate (discussed in document **R-04-T&M-GUIDE-PC**), the applicant for registration as a Professional Engineer must demonstrate the capacity to make recommendations that display responsible behaviour in accordance with the ECSA Code of Conduct.

According to document **R-05-XXX-PE/PT/PN**, demonstrating responsibility at the required level (Level D and Level E) is evidenced by:

- demonstrating a professional approach at all times
- indicating due regard to technical, social, environmental and sustainable development considerations
- seeking advice from a responsible authority on any matter considered to be outside the area of competence
- making decisions and taking responsibility in regard to work output.

Group E: Professional development

As indicated in Table 1 of this document, Group E consists of only one outcome:

Outcome 11 – Undertake sufficient professional development activities to maintain and extend competence.

Outcome 11

How do I know when I have developed and managed my competency?

Outcome 11 concerns Professional Development (PD), which is defined as the activities that a registered professional is required to perform, and these activities must be completed at the required level to maintain registration. PD is the systematic maintenance, improvement and broadening of knowledge and skills and the development of the personal qualities that are necessary for the execution of professional and technical duties throughout an engineer's career.

A registered Professional Engineer is required to maintain and extend competence and at minimum, must complete CPD at the required level to maintain registration.

Professional Development activities carried out between graduation and applying for professional registration is termed Initial Professional Development (IPD). This is an integral part of the professional competence that is required to practise safely and effectively in engineering.

The ability to develop and maintain competency is embodied in Outcome 11, namely the ability to undertake sufficient PD activities to maintain and extend competence. This involves more than completing courses or other activities. The emphasis is on the individual's ability to self-develop. This capability has several dimensions:

- Taking responsibility for one's own development.
- Reflecting on strengths and weaknesses, recognising needs, planning.
- Executing development activities and overcoming obstacles.

An applicant's training towards registration does not have to satisfy formal PD requirements. However, at the time of applying for registration as a professional, the applicant will be assessed on the ability to manage and complete PD-type activities. Pre-registration IPD is not subject to the requirement of annual points. Initial Professional Development involves the initiation of learning activities by the applicant that are distinct from the structured learning activities required by the employer

The essential test is the activity that is appropriate to the specific developmental needs of the individual. Also, involvement of the applicant in planning learning activities is important, rather than simply entrusting this to the employer. The ability to develop one's skills continually is regarded as sufficiently important in an engineering professional to be enshrined as an outcome that must be demonstrated to attain registration.

For a Professional Engineer, it should be noted that boundaries of practice areas change over time; new engineering principles are formulated; new procedures, standards and codes are developed; and engineering practice is advanced. Initial Professional Development should be planned with these factors in mind.

Each of the activities listed below or combinations thereof constitute PD and hence, IPD:

- Attending courses, seminars, congresses and technical meetings organised by engineering institutions/institutes, universities, other professional bodies and course providers.
- Actively participating in conferences, serving on technical or professional committees and engaging in working groups.
- Undertaking structured self-study (i.e., Using textbooks with examples).
- Taking correspondence courses and studying other supervised study packages.

- Enrolling for formal postgraduate studies (limited credits).
- Writing technical papers or presenting papers or lectures at an organised event.
- Reading of technical papers such as white papers or peer-reviewed articles.
- Conducting research and literature reviews that are part of the engineering design and synthesis process.
- Taking in-house training courses offered by companies.
- Undertaking accredited CPD activities.
- Taking credit-bearing courses at higher education institutions that directly complement the individual's engineering-related knowledge.

Applicants typically demonstrate PD by:

- planning their own PD strategy
- selecting appropriate PD activities
- keeping thorough records of PD strategy and activities
- demonstrating independent learning ability
- completing PD activities.

3.3.2 Engineering activities for a Professional Engineering Technologist:

Group A: Knowledge-based engineering problem-solving

As described in Table 1 of this document, Group A consists of three outcomes:

- **Outcome 1 –** Define, investigate, and analyse broadly defined engineering problems.
- **Outcome 2 –** Design or develop solutions to broadly defined engineering problems.
- **Outcome 3 –** Comprehend and apply advanced knowledge of the embodied in widely accepted engineering principles, practices, procedures, processes, systems or methodologies specific to the jurisdiction in which the candidate or applicant practises.

Problem-solving is a process carried out by individuals or teams to bring about a change from a given state to a desired state by means of multistep or multipath activities that have barriers that must be overcome using knowledge and abilities and taking situational requirements into account. Engineering problem-solving relies on the fundamental engineering sciences and specialised engineering knowledge. Proficiency in solving engineering problems at the level described as *broadly defined* is a characteristic of the competency of a Professional Engineering Technologist.

Problem-solving is the common feature that runs through engineering activities and is required in many engineering activities, including the design, development, research, investigation, planning, implementation, construction and operation of engineering systems and maintenance of plant infrastructure. Competency in problem-solving involves two phases: analysis and solution synthesis as captured in Outcomes 1 and 2 of document **R-02-STA-PE/PT/PN**. Because engineering problem-solving is knowledge-based, Outcome 3 is grouped with Outcomes 1 and 2. However, Outcome 3 also supports other outcomes in line with the notion of integrated performance as described in document **R-02-STA-PE/PT/PN**.

Broadly defined engineering problem-solving is perhaps the best starting point for applicants to determine the level at which they are working. *Broadly defined engineering problem-solving* must be demonstrated for an applicant to be considered for professional registration. Candidates/applicants who are unsuccessful in their application are often either not performing at the level of complexity of problem-solving required or did not convey it appropriately in the reports and the review process.

Outcome 1

What is engineering problem-solving?

An applicant should refer to the suggested test for a *broadly defined engineering problem* that is presented in the Competency Standard, document **R-02-STA-PE/PT/PN**. The test is based on the four logical steps illustrated in Table 4. If there is one or more affirmative answers at each step, the problem is classified as a *broadly defined engineering problem*.

Table 4: Test for a broadly defined engineering problems

Step	Main question	Criteria
Step 1 Identification of the engineering problem:	Is the problem an engineering problem?	a) Does solving the problem require coherent and detailed engineering knowledge underpinning the applicable technology area?

Step	Main question	Criteria
Step 2 Establishment of the level of complexity of the initial problem state:	What is the nature of the problem? Does it have one or more of the characteristics indicated in criteria b, c and d?	b) The problem is ill-posed, is under or over specified and requires identification and refinement into the technology area.
		c) The problem encompasses systems within complex engineering systems.
		d) The problem is classified as falling within typical engineering requirements which are solved in well accepted and innovative ways.
Step 3 Complexity of the problem path from the initial state:	What is encountered in the problem investigation and analysis process? Does it have one or more of the characteristics indicated in criteria e, f, g and h?	e) The problem can be solved by structural analysis techniques / tools / methodologies.
		f) Standards, codes, and procedures must be applied to solve the problem, and justification to operate outside these standards and codes must be provided.
		g) Verification is required for the received information from practice area and variety of sources that interfacing within practice area that are complex, abstract, or incomplete with justification. h) Problem may be solved by involving a variety of issues which may impose conflicting constraints: technical, engineering together with interested and affected parties with defined needs to be considered, including needs for sustainability. Justification may be required.
Step 4 Level of decision-making required and potential consequences:	What is involved in the decision-making while analysing the problem? Does it have either or both characteristics indicated in criteria i and j?	i) Practical solutions to the problem require knowledge and judgement in decision-making in the practice area and require consideration of the interface with other areas.
		j) Decisions have significant consequences that are important in the practice area but may extend more widely.

Outcome 2

How will I know when I am performing adequately at problem-solving?

At completion of the training period, candidates must demonstrate competence in outcomes 1, 2 and 3 through their work. The starting point of training is the level of problem-solving ability of the new graduate. The candidate/applicant is expected to produce the same level of problem-solving in the work environment as that previously produced in the academic environment. The candidate/applicant must develop problem-solving abilities in an environment in which the consequences of engineering decisions and actions are significant. At graduation, the knowledge of the candidate centres on the scientific basis of engineering, engineering technologies, some contextual knowledge and some specialist knowledge. During preparation for registration, knowledge must develop in the candidate's practice area and concentrate on the relevant context in which the candidate/applicant practices.

Mentors, supervisors, and applicants/candidates must plan the progression of tasks and responsibilities to ensure the development of these competencies. They are advised to use suitable planning and recording assessment tools and feedback sessions. The progress of the applicant/candidate should be evaluated against each outcome using the DoR scale in *Table 2* of this document. It should be noted that the same body of work may serve to develop competencies in other groups.

The strategy for developing problem-solving competence to the level required in the workplace and the DoR is illustrated in ***Table** 2* of this document. The following steps are example of developing required competencies:

- Initially, the candidate/applicant assists experienced engineering personnel in their problem analysis and solution activities, receiving detailed guidance and continuous monitoring.
- The candidate/applicant then progresses to contribute individually and as a team member in the solution of engineering problems.
- Finally, the candidate/applicant must achieve Level E DoR, performing individually and as a team member, to solve problems. In this last phase, the candidate/applicant must perform over the entire problem lifecycle.

The candidate/applicant should be given the opportunity to experience *broadly defined engineering problem-solving* in contexts such as design, development, research, investigation, planning, implementation, construction and operation of engineering systems and maintenance of plant infrastructure. The candidate should be encouraged to apply first principles to *broadly defined engineering problems* and to develop and apply specialist and contextual knowledge.

Considering the problem of assessing the performance of an applicant/candidate against Outcomes 1 and 2, the ECSA requires the applicant/candidate to perform a creative, systematic analysis of problems at the required level and to work systematically to synthesise solutions to the problems.

Outcome 1: Systematic analysis follows a schema as presented below. The applicant:

- interprets and clarifies requirements, leading to an agreed definition of the problem to be addressed
- identifies interested and affected parties and their expectations
- gathers, structures and evaluates adequate information relating to the problem
- performs a structured analysis
- evaluates the result of the analysis and revises or refines as required
- documents, reports and conveys outcome to the requesting party.

Outcome 2: A similar schema applies to the synthesis phase. The applicant:

- proposes potential approaches or alternatives to the solution
- conducts a preliminary synthesis following selected approaches
- evaluates potential solutions against requirements and wider impacts
- presents reasoned, economical and contextual engineering arguments and justification for the selected option or preferred solution
- fully develops the selected option or preferred solution
- evaluates the resulting solution
- documents the solution for approval and implementation.

Many types of problems can be offered to demonstrate problem-solving ability. The problem may be a design requirement, an applied research and development requirement or a problematic situation in an existing component, system or process.

The solution may be the design of a component, system or process or a recommendation of the remedy to a problematic situation. Developing solutions to *broadly defined engineering problems* involves more than the actual design. The applicant/candidate is expected to indicate competence in the choice of the systematic approach to provide the solution, demonstrate how alternative options are considered and how the preferred option/solution has been selected by developing detailed design specification requirements and other engineering design documentation.

The level of the analysed problem must be gauged by the test described above to determine its suitability for presentation as evidence of competence.

Problem-solving is the core activity of engineering. A wide range of engineering functions are either specific manifestations of problem-solving or rely on problem-solving at different levels. Some examples follow:

- **Design:** This is the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes. Design involves a transformation from an initial requirement to produce the documented instructions on how to realise the end product. In determining a preferred solution, barriers must be overcome. A design assignment, therefore, is an engineering problem and involves sub-problems that must be addressed.
- **Product or process improvement:** It frequently happens that an existing piece of infrastructure, plant, equipment or process is in need of improvement. The proper process is to analyse the existing state and define the desired final state. A process for moving from the initial to the final state must be developed. Again, the investigation is a problem-solving activity as is the solution synthesis phase.
- **Developing the solution for engineering problems**: This is the part of the design process that is iterative because of the related steps that are used until the appropriate solution is found and a decision is made. This decision is based on several alternatives or

options that are considered against engineering standards or codes of practice in the technology area to meet set parameters or criteria.

Other engineering activities have problem-solving based on engineering knowledge in their practice area. These include planning; research, development, and technology transfer; quality assurance; risk analysis; domain-specific project management; managing engineering processes, safe work practices; environmental protection; sustainability analysis; and systems engineering.

Outcome 3

How will I display my application of engineering and contextual knowledge?

All engineering activities, problem-solving in particular, rely on the applicant comprehending and applying the relevant ECSA benchmarked qualification theory and knowledge that is embodied in widely accepted and applied engineering procedures, processes, systems, tools and methodologies that are specific to the practice area. The statement of Outcome 3 recognises three components comprising the knowledge that must be comprehended by the Professional Engineering Technologist:

- Knowledge is rooted in principles (generally first principles) of general laws of the natural and engineering sciences, technologies, methodologies and the applied principles of good engineering practice.
- It is recognised that individual Professional Engineering Technologists develop specialised knowledge regarding either a generally recognised area or a particular combination of topics. This includes understanding *broadly defined* procedures, codes and techniques that are mathematically, scientifically and engineering based and that underpin teamwork.
- Knowledge specific to the practice area in which the Professional Engineering Technologist practises is essential. This includes knowledge of the society, economy, regulatory system and physical environment in which the Professional Engineering Technologist practises engineering.

Engineering knowledge is too diverse to allow a detailed specification of knowledge for every discipline, sub-discipline or practice area. Rather, it is recognised that each engineering practitioner develops a practice area. The Discipline-specific Training guide document, **R-05-XXX-PE/PT/PN** may be consulted on this topic. The practice area, for example, may be a commonly understood area such as structural engineering or power distribution or may be a particular blend flowing from the individual's experience. Therefore, the engineering knowledge requirements from the Competency Standard, document **R-02-STA-PE/PT/PN**, are stated in generic terms.

For the Professional Engineering Technologist, the engineering knowledge acquired in an accredited engineering programme is the basis for practice area knowledge. Professional Engineering Technologists must be capable of engineering analysis. Engineering knowledge may be used explicitly or tacitly.

Professional Engineering Technologists invariably work in teams with specialists from other engineering disciplines, other engineering role-players, other professionals, contractors and other parties. It is, therefore, essential to have a working knowledge of the discipline and the areas in which interaction is necessary. The applicant needs to be aware that certain engineering disciplines require more diverse cross-discipline interaction and knowledge. However, this depends on the environment and the level at which the Professional Engineering Technologist is performing the work.

Engineering work does not occur in isolation and knowledge of the regulatory requirements regarding health and safety, the environment, the contract, and quality and risk is essential. The application of engineering knowledge as an outcome is normally demonstrated during the design, investigation or operation. The applicant typically undertakes the following:

- Displays mastery of understanding current and emerging technologies in the practice area.
- Applies general and underpinning engineering knowledge to support analysis and provide insight into technologist activities.
- Uses an analytical approach as required.
- Displays working knowledge of areas that interact with the practice area.
- Applies related financial, statutory, safety and management knowledge.

Group B: Managing engineering activities

Groups B, C and D reflect competencies that are all linked to problem-solving (Group A) and are essential to engineering activities at the professional level. For example, taking impacts into account is an important stage in the solution of a problem. Similarly, an engineering operation also has impacts that must be assessed and managed.

As described in *Table 1* of this document, Group B consists of two outcomes:

- **Outcome 4 –** Manage part or all of one or more *broadly defined engineering activities*.
- **Outcome 5 –** Communicate clearly with others in the course of their *broadly defined engineering activities*.

Outcome 4

What are engineering managing competencies?

Competent Professional Engineering Technologists must not only perform engineering functions but must also manage engineering activities. Two statements of management competency in Group B described in the Competency Standard, document **R-02-STA-PE/PT/PN**, are as follows:

- Competency to manage *broadly defined engineering activities* must be demonstrated.
- Linked with management is the ability to communicate with those involved in the engineering activities.

Engineering management can be defined as the application of the generic management functions of planning, organising, leading and controlling together with engineering knowledge in contexts that include the management of projects, construction, operations, maintenance, quality, risk, change and business. The level of engineering management that a person is involved in or is sufficiently experienced to do is of necessity limited at the stage of applying for registration as a Professional Engineering Technologist. However, the applicant must take on the responsibility necessary to demonstrate competency under the guidance of suitable competent persons, as described in the Training and Mentoring Guide, document **R-04-T&M-GUIDE-PC**.

Engineering management is more than project management. Project management is in most cases supportive of engineering activity but does not represent the level of demonstration of performance at the degree of responsibility required.

What level of activities must I be able to manage?

The Competency Standard, document **R-02-STA-PE/PT/PN**, provides a test of whether a given engineering activity is classed as a *broadly defined engineering activity*. The test for a *broadly defined engineering activity* is summarised in *Table 1* of this document. The test is applied to the activity itself to determine the complexity of its scope and operating environment, its resource intensiveness, the severity of constraints and the risks and consequences. This test is not independent of the test for *broadly defined problem-solving*; most of the factors are those that give rise to barriers in the problem-solving process and also render the problem *broadly defined*.

The definition of the required level of activity as described in the Competency Standard, document **R-02-STA-PE/PT/PN**, does not imply that applicants in every category work at that level all the time. Rather, candidates/applicants in each category must demonstrate the ability to practise at the required level. Similarly, at the culmination of training, applicants must be able to demonstrate that they are capable of performing the required actions at the required level by having in effect done so in the work situation.

The strategy for developing problem-solving competence to the level required in the workplace and to the degree of responsibility is illustrated in *Table 2* of this document**.**

The various phase activities of an applicant assist in developing the ability to plan, organise, lead and control. The applicant must be able to perform these functions both alone and in a team. Conducting engineering work on one's own or in a team requires planning and organising to attain the required engineering outcomes. Team participation and contribution as a team member and as a leader give the opportunity to demonstrate leadership and the ability to control on a limited scale.

Outcome 5

How do I know when I am managing and communicating at the required level?

Technical communication at a level that supports analysis, synthesis and implementation of solutions is an inherent part of engineering work. The applicant needs the opportunity to communicate orally and in writing about not only engineering matters but also the financial, social, cultural, environmental and political aspects of engineering activity.

In fulfilling Outcome 5, the applicant is expected to demonstrate personal and work process management abilities:

- Manage self.
- Work effectively in a team environment.
- Manage people, work priorities, work processes and resources.
- Establish and maintain professional and business relationships; effective communication can be demonstrated by the ability to write clear, concise and effective reports that are technically, legally and editorially correct using a structure and style that meets communication objectives and user/audience requirements.
- read and evaluate engineering and legal matter relevant to the function of the Professional Engineering Technologist.
- Receive instructions and ensure correct interpretation.
- Issue clear instructions to subordinates using appropriate language and communication aids and ensure that language and other communication barriers are overcome.
- Undertake oral presentations using structure, style, language, visual aids and supporting documents appropriate to the audience and purpose.

This communication competency (Outcome 5) is evaluated in two components via the following:

- Applicant's written application for registration.
- During the oral professional review/interview process in which the applicant is required to make a presentation and answer engineering questions on the applicant's experience.

Group C: Risk and impact mitigation

As described in *Table* 1 of this document, Group C consists of two outcomes:

- **Outcome 6** – Recognise and address the reasonably foreseeable social, cultural, and environmental effects of *broadly defined engineering activities*.
- **Outcome 7 –** Meet all legal and regulatory requirements and protect the health and safety of persons in the course of the *broadly defined engineering activities*.

These outcomes deal respectively with the impacts of engineering activity that are not subject to regulation but rely on the professionalism of the applicant and the impacts that are subject to regulation, both specific and general.

Outcome 6 (impacts of engineering), Outcome 7 (legal and regulatory aspects) and Outcome 8 (ethical behaviour in Group D) reflect the professional behaviour and attitudes expected of a Professional Engineering Technologist. These are supported by knowledge of the context in which the individual practises (an aspect of Outcome 3). It is recognised that during candidacy, exposure to these issues is not as intensive as for an experienced Professional Engineering Technologist. Candidates are, therefore, expected to supplement experience by reading and reflecting on these issues before applying for registration.

Appendix A of this document and the Discipline-specific Training Guide **R-05-XXXPE/PT/PN** list materials that should be consulted and relevant legislation. Both candidates and applicants should also make use of suitable IPD courses in these areas.

Outcome 6

How do I know when I am able to analyse and manage the impacts, benefits and consequences of engineering activities?

Engineering activities deliver benefits to society and the economy in the form of infrastructure, services and goods. Engineering involves the harnessing and control of natural forces or the use and control of complex information. The actions inherent in engineering activities have accompanying risks. These risks must be mitigated to a level that is acceptable to the affected parties. The management of risk accompanying engineering activity is the very rationale for the regulation of the profession. Some risks are well known and understood and the means of addressing them may be embodied in regulation, for example, pressure vessel design.

Other situations may not occur frequently or may occur for the first time with the application of new technology and consequently may not be regulated. Certain risks may have objective technical measures, while others are subject to the judgement of individuals and communities. Some risks may be ethical (Outcome 8 in Group D). The ability to assess and deal with all prevailing risks is integral to the competency of a Professional Engineering Technologist: The Professional Engineering Technologist is expected to be able to identify and to deal with wide-ranging risks associated with engineering work.

The applicant should be given the opportunity to study, analyse and recommend measures for

- social / cultural impacts
- community/political considerations
- environmental impact
- sustainability analysis
- regulatory conditions
- potential ethical dilemmas.

To show competency in ***impact analysis and mitigation***, the following should be done:

- Identify interested and affected parties and their expectations.
- Identify interactions between engineering considerations and social-cultural and environmental factors.
- Identify environmental impacts of the engineering activity.
- Identify sustainability issues.
- Propose and evaluate measures to mitigate the negative effects of engineering activities.
- Communicate with stakeholders.
- Adopt measures to mitigate the negative effects of engineering activities.

Outcome 7

How do I know when I have met all the legal and regulatory requirements in the course of my engineering activities?

Outcome 7 is concerned with explicitly regulated aspects of engineering practice and more general legislation that may apply. Applicants should ascertain the legislation that applies in their work environment. Appendix A of this document and the Discipline-specific Training Guide **R-05- XXX-PE/PT/PN** list certain recommended materials that should be consulted, including the relevant legislation.

Of particular importance is occupational health and safety legislation. The following are the principal examples of the Acts applicable in the South African context, as depicted in Appendix A of this document:

- Occupational Health and Safety Act, 85 of 1993, as amended, and the associated regulations.
- Mine Health and Safety Act, ,29 of 1996, as amended.

While certificated engineers have a specific responsibility under these Acts. All Professional Engineers must be cognisant of the Acts and comply with their provisions.

To demonstrate competency *in regulatory aspects*, the applicant should:

- identify the applicable legal, regulatory and health and safety requirements for the engineering activity
- identify the risk and apply defined widely accepted risk management strategies
- select safe and sustainable materials, components, processes and systems
- communicate with parties involved in the legal and regulatory aspects of the work.

Group D: Act ethically, exercising judgement and taking responsibility

As described in *Table 1* of this document, Group D consists of three outcomes:

- **Outcome 8** – Conduct engineering activities ethically.
- **Outcome 9** – Exercise sound judgement in the course of *broadly defined engineering activities.*
- **Outcome 10 –** Be responsible for making decisions on part or all of *broadly defined engineering activities.*

Professional Engineering Technologists must make engineering and managerial decisions that are related to risks arising from their activities. Three outcomes in Group D are concerned with competencies exercised at a personal level.

Outcome 8

How do I know when I have developed the competency to conduct engineering activities ethically?

Outcome 8 has the simple statement: Conduct engineering activities ethically. The baseline for ethical behaviour is the ECSA Code of Conduct, which covers the need to practise ethically and within one's area of competency, to work with integrity, to respect the public interest and the environment, and to uphold the dignity of the profession and one's relationship with fellow professionals. Included is a section on administrative matters that relate to ethical practice. The applicant must study the ECSA Code of Conduct and be aware of its implications in situations that arise in engineering work.

As in other professions and business situations, ethical problems arise in engineering activity. These may relate to business practices, inducements or an unregulated impact, for example, the use of a rare and unsustainable material for a solution that will be required well into the future. The Professional Engineering Technologist must be capable of detecting, analysing and handling ethical dilemmas and problems that arise in the course of engineering activity. This is a non-negotiable aspect of the Code of Conduct and the Professional Engineering Technologist must deal with any ethical problems that arise.

An applicant who is capable of dealing with ethical issues adopts a systematic approach to resolving ethical issues that is typified by:

- identifying the central ethical problem
- identifying affected parties and their interests
- searching for possible solutions to the dilemma
- evaluating each solution using the interests of those involved and according suitable priority
- selecting and justifying a solution that most appropriately resolves the dilemma.

Outcome 9

How do I know when I have exercised sound judgement in the course of broadly defined activities?

Professional Engineering Technologists are expected to make decisions in situations where the information to underpin the decision may be complex (i.e., the information has more than one part with interactions between parts or the information is incomplete). Such decision-making requires due care by Professional Engineering Technologists and may be informed by experience. Professional Engineering Technologists must therefore have the ability to think of many matters at once and consider their interdependence, their relative importance and their consequences. This process is known as exercising judgement within *broadly defined engineering activities* or in the solution of *broadly defined engineering problems*.

According to the Training and Mentoring Guide, document **R-04-T&M-GUIDE-PC**, applicants should be challenged and given the opportunity to:

- make decisions when full information is not available
- use engineering judgement
- take due care that the outputs and the impacts of an assignment are addressed
- self-assess their competence from time to time.

All the above should be done under the supervision and guidance of a suitably qualified person as described in document **R-04-T&M-GUIDE-PC**.

Additionally, the indication that an applicant exhibits engineering judgement is typically demonstrated by:

- considering several factors, some of which may not be well defined or may be unknown
- considering the interdependence, interactions and relative importance of factors
- foreseeing consequences of actions
- evaluating a situation in the absence of full evidence
- drawing on experience and knowledge
- justifying judgements in regard to risks associated with decisions.

Outcome 10

How do I know when I have taken responsibility for broadly defined engineering activities?

Professional Engineering Technologists are accorded professional status in society by their competence and the facts that the profession self-regulates and that professionals are accountable for their actions. The person registering as a Professional Engineering Technologist must, therefore, understand the obligation to be responsible and to have experience in making decisions since wrong decisions can have adverse consequences. Subject to the limitations regarding taking responsibility as an applicant as discussed in document **R-04-T&M-GUIDE-PC**, the applicant for registration as a Professional Engineering Technologist must demonstrate the capacity to make recommendations that display responsible behaviour in accordance with the ECSA Code of Conduct.

According to document **R-05-XXX-PE/PT/PN**, being responsible at the required degree of responsibility (Levels D–E) is evidenced by:

- demonstrating a professional approach at all times
- exhibiting due regard to engineering, social, environmental, and sustainable development considerations
- seeking advice from a responsible authority (or other professional) on any matter considered to be outside the area of competence
- making decisions and taking responsibility for work output.

Group E: Professional Development

As described in Table 1 of this document, Group E consists of only **Outcome 11:** Undertake professional development activities sufficient to maintain and extend competence.

Outcome 11

How do I know when I have developed and managed my competency?

Outcome 11 concerns IPD that consists of activities identified to meet the requirements before registration. Professional Development activities carried out between graduation and applying for professional registration is termed IPD This is an integral part of the professional competence that is required to practise engineering safely and effectively. It should be noted that IPD changes to CPD after professional registration.

Continuing Professional Development is defined as the activities that a registered professional is required to maintain and complete at the required level to maintain registration. Continuing Professional Development is the systematic maintenance, improvement and broadening of knowledge and skills and the development of personal qualities necessary for the execution of professional and engineering duties throughout the career of a Professional Engineering Technologist.

The ability to develop and maintain competency is embodied in Outcome 11, namely the ability to undertake PD activities sufficient to maintain and extend competence. This involves more than completing courses or other activities. The emphasis falls on the individual's ability to self-develop.

This capability has several dimensions:

- Take responsibility for one's own development.
- Reflect on strengths and weaknesses and recognise needs and plans.
- Execute development activities and overcome obstacles.

Candidates training towards registration do not have to satisfy formal professional development requirements. However, at the time of applying for registration as a professional, candidates will be assessed on their ability to manage and to complete PD-type activities. Pre-registration IPD is not subject to an annual points requirement. Initial Professional Development involves learning activities initiated by the applicant that are distinct from the structured learning activities required by the employer.

The essential test is the activity that is appropriate for the specific developmental needs of the individual. In addition, rather than leaving the planning of learning activities to the employer, the role of the applicant regarding this is important. The ability to develop one's skills continually is seen as sufficiently important in an engineering professional to be enshrined as an outcome that must be demonstrated to attain registration.

For a Professional Engineering Technologist, it should be noted that boundaries of practice areas change over time, new engineering principles are formulated, new procedures, standards and codes are developed, and engineering practice is advanced. Initial Professional Development should be planned with these factors in mind.

Each of the activities listed below or combinations thereof constitute CPD and hence IPD:

- Attending courses, seminars, congresses and technical/engineering meetings organised by engineering institutions/institutes, universities, other professional bodies and course providers.
- Actively participating in conferences, serving on engineering committees, professional committees and in working groups.
- Undertaking structured self-study (i.e., using textbooks with examples).
- Taking correspondence courses and studying other supervised study packages, including e-learning (i.e., online courses).
- Enrolling for formal postgraduate studies (limited credits).
- Writing technical / engineering papers and presenting papers or lectures at organised events.
- Reading technical / engineering papers such as white papers or peer-reviewed articles.
- Studying engineering literature (i.e., Journals and magazines).
- Conducting research and literature reviews that are part of the engineering design and synthesis process.
- Attending in-house training courses offered by companies.
- Participating in accredited CPD training activities.
- Taking credit-bearing courses in higher education institutions that directly complement an individual's engineering-related knowledge.

An applicant typically demonstrates professional development by:

- planning their own professional development strategy
- selecting appropriate professional development activities
- keeping thorough records of professional development strategies and activities
- demonstrating independent learning ability
- completing professional development activities.

3.3.3 Engineering activities for a Professional Engineering Technician

Group A: Knowledge-based engineering problem-solving

Problem-solving is a process carried out by individuals or teams to bring about a change from a given state to a desired state by means of multistep or multipath activities that have barriers that must be overcome using knowledge and abilities and taking situational requirements into account. Engineering problem-solving is distinguished by requiring engineering knowledge; that is, it relies on fundamental engineering activities and specialised engineering knowledge. Proficiency in solving engineering problems at the level described as *well-defined* is a characteristic of the competency of a Professional Engineering Technician.

Problem-solving is the common thread that runs through engineering activities including design, planning, implementing and constructing in addition to operating and closing engineering systems, infrastructure and plants. Competent problem-solving has two phases, analysis and solution synthesis, as captured in Outcomes 1 and 2 of document **R-02-STA-PE/PT/PN**. Because engineering problem-solving is knowledge-based, Outcome 3 is grouped with Outcomes 1 and 2. However, Outcome 3 also supports other outcomes, as depicted in Figure 2.

The test for a *well-defined* engineering problem, which is presented in document **R-02-STA-PE/PT/PN**, is based on four logical steps:

- **Step 1:** Factor a) establishes if a problem is, in fact, an engineering problem by virtue of requiring engineering knowledge. For example, a person performing only project management functions with no role in the engineering aspects of a project would not be solving an engineering problem.
- **Step 2:** Factors b), c) and d) establish the factors that describe complexity of the initial state and the desired end state of the problematic situation: How many factors are known or specified? What is unknown? Are there multiple goals?
- **Step 3:** Factors e) to h) test the complexity of the solution path or process from the initial state to the goal state.
- **Step 4:** Factors i) and j) test the level of decision-making needed in the process of solving the problem and evaluating the solutions and the possible consequences for which responsibility must be taken

Table 5: Test for a well-defined engineering problem

Step	Main question	Criteria
Step 1 Identify the engineering problem	Is the problem an engineering problem?	a) Be solved mainly by practical engineering knowledge that is underpinned by related theory.
Step 2 Establishment of the level of complexity of the initial problem state	What is the nature of the problem? Does it have one or more of the characteristics, b, c or d?	b) Are largely defined but may require clarification. c) Are discreet, focused tasks within engineering systems. d) Are routine and frequently encountered and may be unfamiliar but in a familiar context.
Step 3 Complexity of the problem path from the initial state:	What is encountered in the solution process? Do the solutions have one or more of the characteristics, e, f, g or h?	e) Can be solved in standardised or prescribed ways. f) Are encompassed by standards, codes and documented procedures (require authorisation to work outside limits). g) Require information that is concrete and largely complete but require checking and possible supplementation. h) Involve set of interested and affected parties with defined needs to be taken into account, including needs for sustainability.
Step 4 Level of decision-making required and potential consequences	What is involved in decision-making while solving the problem and in evaluating the solution? Does it have one or more of the characteristics, i or j?	i) Require practical judgement in the practice area of evaluating solutions and considering interfaces with other role-players. j) Rave consequences that are locally important but not far reaching (wider impacts are dealt with by others).

If one or more factors are applicable to each step, the problem is classified as a *well-defined engineering problem.*

Outcome 1

What is engineering problem-solving?

When considering the problem of assessing a person's performance against learning Outcomes 1 and 2, registration requires the applicant to demonstrate the ability to perform a creative, systematic analysis of problems (at the required level) and to work systematically to synthesise solutions to the problems

An example of a schema for the systematic analysis is presented below. The applicant:

- interprets the client's demands, leading to an agreed statement of requirements
- clarifies the requirements and draws issues and impacts to the client's attention
- identifies standards for design aspects and codes and procedures to be followed
- gathers information required for problem analysis
- identifies acceptance criteria for work product
- verifies that the design problem is amenable to solution by his/her techniques
- documents functional solution requirements and gains client acceptance.

A similar schema applies to the synthesis phase. The applicant:

- identifies and analyses alternative approaches for meeting the problem specification
- seeks advice on aspects of the proposal or design process that fall outside established practices or standards
- plans tasks and selects methods to complete the design process
- carries out design or develops solutions and synthesises tasks
- assembles the complete solution and reviews to check compliance with the client's requirements
- checks solution and impacts of solution on interested and affected parties
- reviews documented design with the client to obtain formal acceptance.

Which types of problems could be presented to demonstrate problem-solving ability?

Many types of problems would suffice. The problem may be a design requirement, a development requirement or a problematic situation in an existing component, system or process.

The solution may be the design of a component, system or process or the recommendation of the remedy to a problematic situation. The level of the problem analysed must be gauged by the test described above to determine its suitability for presentation as evidence of competence.

Outcome 2

How will I know when I am performing adequately at problem-solving?

Problem-solving is the core activity of engineering. A wide range of engineering functions are either specific manifestations of problem-solving or rely on problem-solving at different levels. Some examples follow:

- **Design:** This is the systematic process of conceiving and developing materials, components, systems and processes to serve useful purposes. Design involves the transformation from an initial requirement to the documented instructions on how to realise the end product. In the process of developing a solution, barriers must be overcome. A design assignment is therefore an engineering problem and involves sub-problems that must be addressed.
- **Product or process improvement:** It frequently happens that an existing piece of infrastructure, plant or process needs improvement. The proper approach is to analyse the exiting state and define the desired final state. The process for moving from the initial state to the final state must be determined. Again, the investigation is a problem-solving activity as is the solution synthesis phase.

Problem-solving for other engineering activities is based on engineering knowledge of planning, development and technology transfer, quality assurance, risk analysis, domain-specific project management, managing engineering processes, safe work practices, environmental protection, sustainability analysis and systems engineering.

At the end of training, candidates must demonstrate these problem-solving competencies through their work. The starting point of training is the new graduate’s level of problem-solving ability. The complexity level of the engineering problems the graduate needs to solve does not change from tertiary education to the workplace; what changes is that in the workplace, the problem is no longer of an academic nature. The candidate must develop problem-solving abilities in an environment in which the consequences of engineering decisions and actions are significant.

At graduation, the applicant's knowledge centres on the scientific basis of engineering, engineering technologies and some contextual knowledge and specialist knowledge. During candidacy, knowledge must develop in the candidate's practice area and be relevant to the context in which the candidate practises.

Mentors, supervisors and candidates must plan the progression of tasks and responsibility to ensure development of these competencies. They are advised to use suitable planning, recording and assessment tools. The candidate's progress should be evaluated against each outcome using the DoR scale in ***Table** 2* of this document **R-04-T&M-GUIDE-PC**. It should be noted that the same body of work may serve to develop competencies in other groups.

The strategy for developing problem-solving competence to the level required in the workplace and the DoR is illustrated in *Table 2* of this document. The following steps are example of developing required competencies:

- Initially, the candidate/applicant assists experienced engineering personnel in their problem analysis and solution activities, receiving detailed guidance and continuous monitoring.
- The candidate/applicant then progresses to contribute individually and as a team member in the solution of engineering problems.
- Finally, the candidate/applicant must achieve Level E DoR, performing individually and as a team member to solve problems. In this last phase, the candidate/applicant must perform over the entire problem lifecycle.

The candidate should be given the opportunity to experience well-defined problem-solving in contexts such as design, investigation, process or product improvement and planning. The candidate should be encouraged to apply first principles to *well-defined problems* and to develop and apply specialist and contextual knowledge.

Outcome 3

How will I display my application of engineering and contextual knowledge?

All engineering activities and problem-solving rely in particular on a body of knowledge. The statement of Outcome 3 recognises three components regarding the knowledge of a Professional Engineering Technician:

- Knowledge is rooted in principles; that is, the general laws of the natural and engineering sciences and the principles of good engineering practice.
- It is recognised that individual Professional Engineering Technicians develop specialised knowledge that may be in a generally recognised area or may be a particular combination of topics.
- Knowledge that is specific to the environment in which the person practises is essential. This includes knowledge about the society, economy, regulatory system and physical environment in which the person practises engineering.

Engineering knowledge is too diverse to allow a detailed specification of knowledge for every discipline, sub-discipline or practice area. Rather, it is recognised that each engineering practitioner develops a practice area. This may be a commonly understood area such as structural engineering or power distribution, or may be a particular blend arising from the individual's experience. The knowledge requirements in document **R-02-STA-PE/PT/PN** are therefore stated in generic terms.

For Professional Engineering Technicians, the technical knowledge acquired in the undergraduate programme is the basis for practice area knowledge and Professional Engineering Technicians must be capable of practical analysis. Technical knowledge may be used explicitly or tacitly.

Professional Engineering Technicians invariably work in teams with specialists, engineering role-players, contractors and other parties from other engineering disciplines. It is, therefore, essential to have a working knowledge of the discipline and the areas in which interaction is necessary.

Engineering work does not occur in isolation and knowledge of health and safety, environmental, contractual, quality and risk regulatory requirements is essential

This outcome is normally demonstrated in the course of design, investigation or operations. The applicant typically:

- displays mastery of established methods, procedures and techniques in the practice area
- applies the knowledge that underpins methods, procedures and techniques to support technician activities
- displays working knowledge of areas that interact with the practice area
- applies codified knowledge in related areas (i.e., financial, statutory, safety, management)
- uses information technology effectively as required in the practice area.

Group B: Management of engineering activities

Groups B, C and D reflect competencies linked to problem-solving and are essential to engineering activities at the professional level. For example, considering impacts is an important stage in the solution of a problem. Similarly, an engineering operation also has impacts that must be assessed and managed.

Outcome 4

What are engineering managing competencies?

Competent engineering practitioners must not only perform technical functions but must also manage engineering activities. Two statements of management competency are presented in Group B in document **R-02-STA-PE/PT/PN**. Competency to manage *well-defined engineering activities* must be demonstrated as being linked with engineering management, and the ability to communicate with those involved in the engineering activities must be evidenced.

Engineering management can be defined as the application of the generic management functions of planning, organising, leading and controlling together with engineering knowledge in contexts including the management of projects, construction, operations, maintenance, quality, risk, change and business. The level of engineering management in which a candidate is either involved or sufficiently experienced is invariably limited at the stage of applying for registration as a Professional Engineering Technician.

Engineering management is more than project management. Project management is, in most cases, supportive of technical engineering activity. Work that is predominantly project management with minor technical engineering content is unacceptable as a demonstration of performance at the degree of responsibility in Group E.

The Competency Standard, document **R-02-STA-PE/PT/PN**, provides a test to determine whether a given engineering activity is classed as a *well-defined engineering activity*. The test is applied to the activity itself to determine the complexity of its scope and operating environment, resource intensiveness and the severity of constraints, risks and consequences. This test is not independent of the test for *well-defined* problem-solving. Most of the factors that give rise to barriers in the problem-solving process also render the problem *well defined*.

The definition of the required level of activity in document **R-02-STA-PE/PT/PN** does not imply that practitioners in every category work at the level stipulated all the time. Rather, the practitioner in each category must demonstrate the ability to practise at the required level. Similarly, at the culmination of training, the applicant must demonstrate capability of performing the required actions at the required level through actual work done in the work situation.

The progression of levels of engineering work and degrees of responsibility defined in document **R-04-T&M-GUIDE-PC**, namely *Being exposed, Assisting, Participating, Contributing* and *Performing*, also apply to the management outcomes and the communication outcome at the stage of applying for registration as a Professional Engineering Technician.

Various candidates phase activities assist in developing the ability to plan, organise, lead and control. The applicant must be able to perform these functions, both alone and in a team. Conducting engineering work on one's own or in a team requires planning and organising to attain the required technical outcomes. Team participation and contribution as a team member and as a leader give the opportunity to demonstrate leadership and the ability to control on a limited scale.

Outcome 5

How do I know when I am managing and communicating at the required level?

Technical communication at a level that supports analysis, synthesis and the implementation of solutions is an inherent part of engineering work. The applicant needs the opportunity to communicate orally and in writing not only about engineering matters but also about the financial, social, cultural, environmental and political aspects of engineering activity.

The applicant is expected to display personal and work-process management abilities:

- Manage self.
- Work effectively in a team environment.
- Manage people, work priorities, work processes and resources.
- Maintain professional and business relationships.

Effective communication can be demonstrated by:

- writing clear, concise and effective reports that are technically, legally and editorially correct using a structure and style that meet communication objectives and user/audience requirements
- reading and evaluating technical and legal matters relevant to the function of the Professional Engineering Technician
- receiving instructions and ensuring correct interpretation
- issuing clear instructions to subordinates using appropriate language and communication aids, thus ensuring that language and other communication barriers are overcome
- making oral presentations using structure, style, language, visual aids and supporting documents appropriate to the audience and purpose.

Group C: Risk and impact mitigation

As described in *Table* 1 of this document, Group C consists of two outcomes:

- **Outcome 6 –** Recognise and address the reasonably foreseeable social, cultural, and environmental effects of *well-defined engineering activities*.
- **Outcome 7 –** Meet all legal and regulatory requirements and protect the health and safety of persons in the course of the *well-defined engineering activities*.

These outcomes deal respectively with the impacts of engineering activity that are not subject to regulation but rely on the professionalism of the applicant and the impacts that are subject to regulation, both specific and general.

Outcome 6 (impacts of engineering), Outcome 7 (legal and regulatory aspects) and Outcome 8 (ethical behaviour in Group D) reflect the professional behaviour and attitudes expected of a Professional Engineering Technician. These are supported by knowledge of the context in which the individual practises (an aspect of Outcome 3). It is recognised that during candidacy, exposure to these issues is not as intensive as for an experienced Professional Engineering Technician. Candidates are, therefore, expected to supplement experience by reading and reflecting on these issues before applying for registration.

Appendix A of this document and the Discipline-specific Training Guide **R-05-XXXPE/PT/PN** list materials that should be consulted and relevant legislation. Both candidates and applicants should also make use of suitable IPD courses in these areas.

Outcome 6

How do I know when I am able to analyse and manage the impacts, benefits and consequences of engineering activities?

Engineering activities deliver benefits to society and the economy in the form of infrastructure, services and goods. Engineering involves the harnessing or the mitigation of the effects of natural forces or the use and control of information. The actions inherent in engineering activity have accompanying risks. These risks must be mitigated to a level that is acceptable to the affected parties. The management of risk accompanying engineering activity is the very rationale for the regulation of the profession. Some risks are well known and well understood, and the means of addressing them may be embodied in regulation, for example, pressure vessel design. Other situations may not occur frequently or may occur for the first time with the application of new technology and may not, in consequence, be regulated. Certain risks may have objective technical measures, while others are subject to the judgement of individuals and communities. Some risks may be ethical (Outcome 8 in Group D). The ability to assess and deal with all prevailing risks is integral to the competency of an engineering practitioner.

The Professional Engineering Technician is expected to be able to identify and deal with wide-ranging risks associated with engineering work.

The two outcomes in Group C, Outcomes 6 and 7 as defined in document **R-02-STA-PE/PT/PN**, deal respectively with the impacts of engineering activity that are not subject to regulation but rely on the professionalism of the practitioner and the impacts that are subject to regulation, both specific and general.

Outcome 7

How do I know when I have met all the legal and regulatory requirements in the course of my engineering activities?

Outcome 7 is concerned with explicitly regulated aspects of engineering practice and the more general legislation that may apply. Candidates must ascertain the legislation that applies in their work environments. Appendix A provides a list of Acts that apply generally and in specific areas. Applicants are reminded that this list is provided for information only and is not exhaustive. The onus rests on each applicant to identify the applicable and current legislation.

Of particular importance is occupational health and safety legislation. The following are the principal examples of the Acts applicable in the South African context, as depicted in Appendix A of this document:

- Occupational Health and Safety Act, 85 of 1993, as amended, and the associated regulations.
- Mine Health and Safety Act, ,29 of 1996, as amended.

While certificated engineers have a specific responsibility under these Acts. All Professional Engineers must be cognisant of the Acts and comply with their provisions.

Outcomes 6 and 7 in the Competency Standard are relevant to the cluster of competencies presented below.

The applicant should be given the opportunity to study, analyse and recommend measures for

- social/cultural impacts
- community/political considerations
- environmental impacts
- sustainability analysis
- regulatory conditions
- potential ethical dilemmas.

To demonstrate competency in impact analysis and mitigation, the applicant should:

- identify interested and affected parties and their expectations
- identify environmental impacts of the engineering activity
- identify sustainability issues
- propose measures to mitigate negative effects of engineering activity
- communicate with stakeholders.

To demonstrate competency in regulatory aspects, the applicant should:

- identify applicable legal, regulatory and health and safety requirements for the engineering activity
- select safe and sustainable materials, components, processes and systems, seeking advice when necessary
- apply defined, widely accepted methods to identify and manage risk.

Outcome 6 (impacts of engineering), Outcome 7 (legal and regulatory aspects) and Outcome 8 (ethical behaviour in Group D) reflect the professional behaviour and attitudes expected of a Professional Engineering Technician. These are supported by knowledge of the context of the individual practices (aspect of Outcome 3). It is recognised that during candidacy, exposure to these issues may not be as intensive as for an experienced, registered engineering technician. Applicants are, therefore, expected to supplement experience by reading and reflecting on these issues before applying for registration. Appendix A and the Discipline-specific Training Guides list material that should be consulted, including the relevant legislation. Applicants should also make use of suitable CPD courses in these areas.

Group D: Act ethically, exercising judgement and taking responsibility

Engineering practitioners must make technical and managerial decisions related to the risks arising from their activity. Three outcomes in Group D are concerned with competencies exercised at a personal level.

Similar to other professions and business situations, ethical problems arise in engineering activity. These may relate to business practices, inducements or an unregulated impact, for example, the use of a rare, unsustainable material for a solution that will be required well into the future. Professional Engineering Technicians must be capable of detecting, analysing and dealing with ethical dilemmas and problems that arise in the course of engineering activity. This is a non-negotiable aspect of the ECSA Code of Conduct and Professional Engineering Technicians must address any ethical problems that arise.

Outcome 8

How do I know when I have developed the competency to conduct engineering activities ethically?

Outcome 8 simply states: Conduct engineering activities ethically. The baseline for ethical behaviour is the ECSA Code of Conduct as published in terms of the Engineering Profession Act, 46 of 2000.

The Code of Conduct covers the need to practise ethically and within one's area of competence, work with integrity, respect public interest and the environment and uphold the dignity of the profession, including one's relationship with fellow professionals. There is also a section on administrative matters that relate to ethical practice. The candidate must study the ECSA Code of Conduct and be aware of its implications in situations that arise in engineering work.

Outcome 9

How do I know when I have exercised sound judgement in the course of broadly defined activities?

Professional Engineering Technicians are expected to make decisions in situations where the information to underpin the decision may be incomplete or may be complex, that is, it has more than one part, with interactions among the parts. Such decision-making requires due care by the practitioner and may be informed by experience. Professional Engineering Technicians must therefore have the ability to think of more than one matter at once together with their interdependence, their relative importance and their consequences. This process is known as exercising *judgement* within *well-defined engineering activities* or exercising *judgement* in the solution of *well-defined engineering problems.*

Applicants should be given the opportunity and be challenged to:

- make decisions when full information is not available
- take due care that the outputs and the impacts of the assignment are addressed
- self-assess their competence from time to time.

To demonstrate sensitivity and capability in dealing with ethical issues, the applicant should adopt a systematic approach to resolving these issues that is typified by:

- identifying the central ethical problem
- identifying affected parties and their interests
- searching for possible solutions for the dilemma
- evaluating each solution using the interests of those involved and according suitable priority
- selecting and justifying the solution that is best to resolve the dilemma.

Exhibiting judgement is typically demonstrated by:

- considering a limited number of factors, some of which may not be well defined
- considering the interdependence, interactions and relative importance of factors
- foreseeing consequences of actions
- evaluating a situation in the absence of full evidence
- drawing on experience and knowledge.

Outcome 10

How do I know when I have taken responsibility for broadly defined engineering activities?

Engineering technicians are accorded professional status in society by virtue of their competence and because the profession self-regulates and professionals are accountable for their actions. The person registering as a Professional Engineering Technician must, therefore, understand the obligation to be responsible and to have experience in making decisions, which if wrong, could have adverse consequences. Subject to the limitations regarding taking responsibility as a candidate or unregistered person discussed in document **R-04-T&M-GUIDE-PC**, the applicant for registration as a Professional Engineering Technician must demonstrate the capacity to make recommendations that display responsible behaviour.

Being responsible is evidenced by:

- demonstrating a professional approach at all times
- displaying due regard to technical, social, environmental and sustainable development considerations
- taking advice from a responsible authority on any matter considered to be outside one's area of competence
- evaluating work output, revising as required and taking responsibility for work output.

Group E: Professional development

Professional Development is the systematic maintenance, improvement and broadening of knowledge and skills and the development of personal qualities necessary for the execution of professional and technical duties throughout an engineering technician's career. A registered Professional Engineering Technician is required to maintain and extend competence and must complete at least the required level of PD to maintain registration.

Candidates training towards registration do not have to satisfy a formal PD requirement. However, at the time of applying for registration as a professional, applicants are assessed on their ability to manage and complete PD-type activities. This is an integral part of the professional competence required to practise safely and effectively in engineering. The PD-type activity carried out before registration is often termed IPD.

Outcome 11

How do I know when I have developed and managed my competency?

The ability to develop and maintain competency is an essential and demonstrable competency as embodied in Outcome 11, namely the ability to undertake sufficient PD activities to maintain and extend competence. This is more than completing courses or activities. The emphasis falls on the individual's ability to self-develop. This capability has several dimensions: take responsibility for one's own development; reflect on strengths and weaknesses; recognise needs; plan and execute development activities; and overcome obstacles.

The range of methods open to the candidate for presentation of IPD is substantial and comprises reading, researching, in-house training, accredited PD courses, credit-bearing courses in higher education institutions and higher qualification studies that complement the individual's training and work experience. The essential test is to confirm that the activity is appropriate for the specific developmental needs of the individual. Also, involvement of the candidate in the planning of the learning activities rather than simply entrusting this to the employer is important.

The ability to develop one's skills continually is regarded as sufficiently important in an engineering professional to be enshrined as an outcome that must be demonstrated to attain registration.

For a Professional Engineering Technician, it should be noted that boundaries of practice areas change over time, new engineering principles are formulated, new procedures, standards and codes are developed, and new engineering practice is advanced. Initial Professional Development should be planned with these factors in mind.

All the activities listed below, including combinations thereof, constitute PD and thus, IPD:

- Attending courses, seminars, congresses and technical meetings organised by engineering institutions/institutes, universities, other professional bodies and course providers.
- Actively participating in conferences, serving on technical or professional committees and engaging in working groups.
- Undertaking structured self-study (i.e., using textbooks with examples).
- Studying technical literature (e.g., journals, magazines).
- Taking correspondence courses and studying other supervised study packages in addition to taking in-house courses provided by employers.

- Enrolling for formal postgraduate studies (limited credits).
- Writing technical papers or presenting papers or lectures at organised events.

Pre-registration IPD is not subject to the requirement of annual points. Initial Professional Development involves learning activities initiated by the applicant that are distinct from the structured learning activities required by the employer.

Management of one's PD is demonstrated by:

- planning own PD strategy
- selecting appropriate PD activities
- keeping a record of PD strategy and activities
- displaying independent learning ability
- completing PD activities.

4. APPLICANTS IN ACADEMIC, RESEARCH AND MANAGEMENT POSITIONS

In certain cases, applicants are employed in engineering academia as lecturers, in the research and development industry or in highly specialised fields during their development towards registration. While these applicants do not conform to the normal industry employment situation, they nevertheless gain the opportunity for development towards meeting the Competency Standards. These applicants should utilise the opportunities that exist while working with industries with students that apply for research or further studies to investigate real industry problems and participate in complex / broadly defined / well-defined engineering activities with an aim of resolving engineering problems. This way of interaction with industry will bridge the gap of certain outcomes that could not be met / demonstrated in academia environment. Samples or experiments can be undertaken from a real live plant or equipment to verify engineering theories. Most industries have a list of issues or problems to be investigated or benchmark practices waiting to be resolved.

Applicants working in industries at management positions should ensure that they keep themselves abreast of the engineering activities and problems for the IPD and to maintain their CPD points. There are number of areas this can be achieved through, not limited to the following:

- Participate in engineering projects committees as a member or chairperson; this will assist with sound engineering judgements and ensure the meeting packages are reviewed and to challenged their integrity.
- Review the engineering documents that subordinates compile and be part of the approval team.
- Volunteer to lead the engineering problems that arise in the industry and participate as a team member.

Applicants employed in teaching and research positions should be alert to opportunities in their work experience that demonstrate competence against the outcomes. For example, the planning, execution and commissioning of a new and substantial laboratory may provide evidence against a number of outcomes. Applicants should seek opportunities to assist senior colleagues who are registered with the ECSA with consulting work. This engagement, while never full time, should be sustained over a long period. The senior colleague should fulfil a mentorship role and allow the candidate to take on increasing responsibility, moving up to Level E on the responsibility scale. It is likely that the time needed for the lecturer or researcher to obtain the necessary experience at the required level may be longer than in a conventional industrial situation.

5. APPLICANTS WHO HAVE COMPLETED ADVANCED QUALIFICATIONS

The *Training and Mentoring Guide*, document: **R-04-T&M-GUIDE-PC,** indicates the advanced studies that contribute towards training. In addition, the ECSA registration policy allows such applicants to present appropriate aspects (i.e., experimental and investigation) of their advanced studies as part of the evidence of competence against particular outcomes.

5.1 Professional Engineer

Applicants who have completed higher education studies beyond the BEng or the equivalent educational qualification level required for registration as a Professional Engineer should identify opportunities to present evidence at the required level against the outcomes defined in the Competency Standards.

5.2 Professional Engineering Technologist

Applicants who have completed advanced education studies beyond the BTech or equivalent education qualification level (e.g., research degree) for registration as a Professional Engineering Technologist should identify opportunities to present evidence at the required level against the outcomes defined in the Competency Standards. It should be noted that applicants who have a number of years of industry experience with an educational level below the relevant ECSA benchmarked qualification can apply via this alternative route.

5.3 Professional Engineering Technician

Applicants who have completed higher education studies beyond the National Diploma or the equivalent educational qualification level required for registration as a Professional Engineering Technician should identify opportunities to present evidence at the required level against the outcomes defined in the Competency Standards.

REVISION HISTORY

Revision number	Revision date	Revision details	Approved by
Rev. 0 Draft A	08 July 2022	Merging R-08-PE, R-08-PT and R-08-PN into one combined document R-08-CS-GUIDE-PE/PT/PN	RDDR Business Unit
Rev. 0 Draft B	5 August 2022	First Draft submitted by Working Group	Working Group
Rev.0 Draft C	14 August 2022	First Draft review	RDDR, Registration BU and Working Group
Rev.0 Draft D	29 September 2022	Second Draft Review	RDDR, Registration BU and Working Group
Rev.0 Draft E	03 October 2022	Review and recommendation by ERPS	Acting RPS Executive
Rev.0	13 October 2022	Approval	RPSC
Rev 0	01 December 2022	Ratification	Council

The Standard for:

Guide to the Competency Standards for Registration in Professional Categories

Revision 0 dated 13 October 2022 and consisting of 70 pages reviewed for adequacy by the Business Unit Assistant Manager and approved by the Acting Executive: Research, Policy and Standards (**RPS**).

.... 06 December 2022

Business Unit Assistant Manager — Date

.... 06 Decmber 2022

Acting Executive: RPS — Date

This definitive version of this policy is available on our website

APPENDIX A: Examples of legislation applicable generally and in particular areas of engineering

1. Engineering Profession Act, 46 of 2000
2. Occupational Health and Safety Act, 85 of 1993:
   - 2.1 General Machinery Regulations
   - 2.2 Construction Regulations, 2014
   - 2.3 Driven Machinery Regulations
   - 2.4 Pressurised Equipment Regulations
3. Mine Health and Safety Act No. 29 of 1996:
   - 3.1 Design of underground dam walls, plugs and barricades
   - 3.2 Regulations on use of water for mining
4. Environment Conservation Act, 73 of 1989
   - 4.1 National Environmental Management Act, 107 of 1998
   - 4.2 National Environmental Management Waste Act, 59 of 2008
   - 4.3 National Radioactive Waste Disposal Institute Act, 53 of 2008
   - 4.4 National Nuclear Regulator (NNR) Act, 47 of 1999
   - 4.5 Mine and Safety Act, 1996
   - 4.6 SANS 10248, 1023: Waste Classification and Management Regulations from South Africa Constitution Act, 108 of 1996
   - 4.7 Hazardous Substance Act, 5 of 1973
5. National Building Regulations and Building Standards Act, 103 of 1977:
   - 5.1 Certification of structural system of a building or home
   - 5.2 Certification of fire protection system
   - 5.3 Certification of artificial ventilation systems
   - 5.4 Geotechnical site investigations, stability of excavations, geotechnical investigations

on sites underlain by dolomites

5.5 Fire Protection Standard SANS Code 10139: 2012 for fire detection and alarm systems for buildings – system design, installation and servicing

6. National Water Act, 36 of 1998:

   6.1 Various measures relating to pollution of a water resource

   6.2 South Africa Bureau of Standards (SABS) Act, 24 of 1945; Act 29 of 2008

   6.3 List of SABS/TC 147 STANDARDS listing SANS codes for chemical use for treatment of water intended for human consumption and other purposes, e.g., SANS 241:2015 Drinking Water Standard

   6.4 SANS codes for food and beverages e.g., SANS 10133, etc. from www.sans.co.za

7. Water Act, 54 of 1956

   7.1 Determination of persons permitted to design dams

8. ISO 9001: 2015

9. South Africa Bureau of Standards (SABS) Act, 24 of 1945; Act 29 of 2008

10. Nuclear Energy Act, 46 of 1999

    10.1 Minerals and Energy Acts, e.g., Mineral and Petroleum Act, 28 of 2002

11. SANS Codes fromwww.sabs.co.za