‘COMPETENCY STANDARDS FOR THE PIPELINE INDUSTRY’

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COMPETENCY STANDARDS FOR THE PIPELINE INDUSTRY

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ABSTRACT

Pipeline standards and regulations explicitly require personnel to be both competent and qualified to work on pipelines, but they neither define competent or qualified, nor provide methods or processes to demonstrate competence and qualifications.

This paper defines competence and qualification and introduces and describes "competency standards." These standards are used to assess the competence of an individual and are an integral part of the process to qualify individuals as being competent. Individuals are proven to be qualified in a competency if they are successfully assessed against these standards.

The paper recommends the contents of a competency standard: the standard should clearly state its purpose and outcomes, and detail the knowledge, training, mentoring, and experience requirements, as well as an assessment method. Examples of these standards are presented, showing how competency standards provide a common definition of a competence and showing how competencies can be assessed against these standards. A case study of an assessment of an individual is also detailed.

The choice between a prescriptive and a performance-based competency standard is discussed, and it is shown that the choice is affected by the level of the competence, the complexity of the competence, the homogeneity of the industry, and the government regulator's resources and capabilities to police the standard.

The paper explains that qualifications must be "portable": as individuals move jobs, the qualifications they obtain need to be recognized by all companies. Portability is achieved by having the qualification "certified". This certification is conducted by an independent body, which certifies that the processes followed (including any assessments) meet the requirements of the competency standard, and that the assessment and the award of the qualification have been audited and verified. Hence, a qualification is a two-step process: award and certification.

1. Introduction

Organizations often state that "people are our greatest asset." This is true, as we know that the skills and development of our personnel are crucial to business success. But does the leadership of these organizations ensure its personnel have the right skills, are qualified to do their jobs, subject them to continuous development, and verify their skills? This requires leadership; as H. S. Firestone (1868 – 1938, Founder, Firestone Tire and Rubber Company) stated: "*The growth and the development of people is the highest calling of leadership."*

An organization's leadership sometimes needs reminding of this: a recent ruling by the U.S. Pipeline and Hazardous Materials Safety Administration (Federal Register/Vol. 82, No. 67/Monday, April 10, 2017/Rules and Regulations)) stated:

"*This rule mandates… [pipeline] operators verify their… qualification of personnel… including… Management… technical personnel, risk evaluators, operators… [and]… Define the qualification requirements… and… verify personnel satisfy the defined qualification requirements*."

This rule is clear – pipeline operators must "define" and "verify" the "qualifications" of their personnel working on their pipelines. But how is this achieved? What is a "qualification", how do you "define" it, and how do you "verify" personnel?

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A solution is the use of "competency standards", and this paper introduces and describes these standards. They are used to assess the competence of personnel, and there are many examples in the literature, many produced by standards bodies and trade organizations (for example, [1-9]). The standards are an integral part of the process to qualify and certify personnel as being competent; this is an important process, as standards and regulations all over the world explicitly require personnel to be both competent and qualified to work on pipelines [10-12].

It is obvious that all individuals must be competent to perform their job tasks, under all working conditions. These individuals must provide evidence that they possess the required technical skills, knowledge, experience, and behavior to perform their job role/function, and that they can apply them consistently, safely, and in accordance with relevant procedures and standards.

"Providing evidence" means an assessment process is necessary to ensure that individuals are competent to undertake their job tasks. This assessment is conducted using an agreed standard (the competency standard). When individuals pass an assessment, they are awarded a qualification. This qualification is evidence that they possess the competence and have been assessed.

A final step can be introduced into the competence assessment process. An independent body can verify that all stages and aspects of the assessments have been fair, safe, valid, reliable, and consistent. This "certification" ensures the qualification is "portable" (the holder can move to other organizations, and the qualification will be recognized by these other organizations).

This paper[2] focuses on the competency standards needed prior to any assessment or certification but also briefly mentions assessment and certification.

2. Competence

Each one of our workers has a job. These jobs are made up of tasks. The workers require competencies to be able to perform these tasks. Competence[3] is a statement of desired knowledge, skills, and behaviors; therefore, competence is a combination of skills (ability to do a task), knowledge (ability to understand and explain the task), experience (type, years, supervision to obtain the knowledge), and behaviors (Figure 1), but a competency:

- must meet an agreed standard;
- must be updated as competencies can deteriorate or become dated with time, leading to a drift into incompetence ("competence decay");
- must be continually assessed [13], as evidence is needed that it is being absorbed by personnel [1] ("demonstrable competencies" [13,14]); and
- must be applicable under all working conditions.

Therefore, personnel must have their competencies assessed against a standard. This assessment could be by examination, interview, performance, etc., but it must be formal and recorded.

3. Competence Level

Different jobs will require differing levels of competence. Junior personnel will be heavily supervised and will be performing low-level tasks. Senior personnel will be performing high-level tasks, with no supervision**.** Consequently, the competencies detailed in a competency standard must specify the level of competence. These levels could be [1-9]: Foundation, Practitioner, or Expert (Table 1). Additionally, an "Awareness" level can be used as an entry level into these three levels of competence [15]. These increasing competence levels correspond with increasing job responsibilities. Each level must contain the characteristics of competent personnel [16]. They must have:

- sufficient knowledge of the tasks to be undertaken and the risks involved;
- the experience and ability to carry out their duties and recognize their limitations**.**

4. Competency Standard

Competencies of a job holder need to be assessed against a defined standard to ensure validation. "Competency standards" provide a common definition of a competence, with its minimum requirements [13]. It is best to keep these standards simple, measurable, and auditable [10-12]. Hence, the competency standard must detail "outcomes"[4] [17]: what the job holder will be able to do in some measurable way (there may be more than one measurable outcome defined for a given competency) [18]. These outcomes should cover [13]:

- "ability"… is able to do a task (this is "skill");
- "understanding"… is able to understand and explain the task (this is "knowledge");
- "supervision"… is able to manage personnel with these abilities and/or understanding;
- "training"… is able to train personnel with these abilities and/or understanding, and/or supervisory abilities.

The outcomes should be clear, detail the expected characteristics of the competency, and be phrased to allow an assessment (Table 2 [19]): the outcomes imply the assessment criteria.

[2] See Appendix A for Terminology and Definitions.
[3] "Competence" can be viewed as the total ability of the individual, whereas a "competency" is a single skill.
[4] A (learning) outcome identifies what the candidate knows and is able to do, or, will know and be able to do by the end of a course or program. The outcomes are measurable and are used in assessing candidates.

A typical competency standard would contain the detail presented in Table 3 [1-9]. The standard will also require the method of assessment (e.g., by examination) and how long the competency is valid (i.e. when does it require reassessment).

A simple approach to writing competency standards allows an easy guide and rapid adoption; therefore, competency standards need to be short by, for example, limiting competency descriptions to a single sentence [10].

It should be emphasized that a competency standard gives the minimum requirements for a competency.

Appendix B presents an example of a competency standard.

5. Should a Competency Standard be "Prescriptive" or "Performance-based"?

A "standard" [20, 21] is: "*a set of technical definitions and guidelines that function as instructions for designers, manufacturers, operators or users of equipment to provide consistent and comparable results.*" It is [22] "*an agreed, repeatable way of doing something.*"

A standard will have wide-ranging applications and will be used by many different organizations; for example, the well-known ISO 9000 family of standards covers various aspects of quality management, and provides guidance and tools for all companies and organizations who want to ensure that their products and services consistently meet customers' requirements and that quality is consistently improved.

Some standards are essentially advice and guidance, but others are much more prescriptive and set out absolute requirements that have to be met if a user wishes to make a claim of compliance with the standard [22]. Standards can give choices and options (rather that requirements) and can allow different procedures for unusual conditions; traditionally; however, standards are clear about what needs to be done to achieve compliance, but can be difficult to apply in novel circumstances.

Traditionally, there can be two main approaches to setting standards [23]:

- Prescriptive – tell people what to do.
- Performance (goal-based or outcome-based) – tell people what they need to achieve.

Obviously, a third approach is a mix of prescriptive and performance.

Prescriptive standards will require constant updating, as technologies change, processes change, regulations change, etc. This is a long-term commitment. "Performance" or "goal-based" standards offer more flexibility but raise a major concern: they introduce ambiguity about what is required to achieve compliance. Goal-based standards will require minimal updating.

The same definitions apply to regulations [24]:

- Prescriptive regulation: the regulator prescribes standards and the process to which the entity must adhere in order to meet the standard.
- Performance-based regulation: the regulator specifies required outcomes but leaves the means of achieving that outcome to the discretion of the regulated entity. Regulators specify a standard for firms but do not require firms to follow specific procedures to meet the standard.

These differing approaches can be viewed as [25]:

- Prescriptive (must be adopted or implemented, and if it is a regulation, it is required for compliance): "checklist" compliance with standards having industry-wide application.
- Performance (ends to be achieved [or outcomes to be avoided] by specifying a desired outcome but not how to achieve it): gives flexibility to organizations to customize their actions to circumstances and to concentrate on enhancing the performance of their internal risk management actions.

Goal-setting standards and regulations set out what must be achieved but not how it must be done, whereas prescriptive standards and regulations spell out in detail what should be done [26]. The goal-setting approach will require some explicit guidance through published guides (e.g., [27, 28]).

6. What is the Best Basis for a Competency Standard?

The pipeline industry is moving into management-based standards [e.g., 29, 30]. These standards are often seen as performance-based, but they do not usually require organizations to achieve specified ends or performance outcomes, such as a demonstrable reduction in major incidents. Summarizing [25]:

- Prescriptive approach: targets individual components of, or pathways to, a larger problem, using clear actions, commanding the use of means; i.e., it is the "means" of avoidance, not the "ends".
- Management-based: directs attention to that larger problem itself, using clear actions, and it is focused on the "means" not the "ends".
- Performance-based: targets individual components of, or pathways to, a larger problem, and it is focused on the attainment or avoidance of some "ends" rather than the "means".

All these approaches have advantages and disadvantages: for example, the prescriptive approach is easy to communicate, follow, and comply with, but it is inflexible, whereas the performance-based approach is flexible but may be difficult to interpret, monitor, or establish compliance.

Many factors will affect the choice; for example, if an industry in "homogeneous" (similar technologies, equipment, processes, etc.), a prescriptive approach will be easy and appropriate, but if the industry is heterogeneous, a more performance-based

approach may be more appropriate [25]. A better way to assess the best approach is to adopt the methodology suggested for regulations. Three main factors govern the choice between a prescriptive and a performance-based regulation [25]:

- The nature of the problem to be solved (understanding [good or bad] of risks, consequences, frequency, etc.?);
- The characteristics of the regulated industry (incentives to follow regulations, culture, a few big organizations or many small organizations, technological diversity, rate of change, etc.?); and,
- The regulator's resources and capacities (legal authority, political/public expectations, sensitivity to administration and procedural constraints, budget resources, time, etc.?).

This is a reasonable approach (Figure 2), as – ultimately – it is a regulator who will decide on the appropriateness of a standard used in an industry.

A final point about competency standards: prescriptive standards for engineering personnel will be very difficult, compared to technical/field personnel. Consider a field technician, who will have clearly defined roles and tasks, often linked to common equipment or processes. ASME B31Q [5] gives good examples of competence requirements for field personnel; Table 4 summarizes an example.

Table 4 shows a task that is easily identified and broken down into clear actions that are easily assessed. This prescriptive approach would be difficult to replicate for personnel such as design engineers, where their tasks will be multiple, inter-relating, and varied, with the detail, processes (e.g., standards), and technologies (e.g., software) changing on a regular basis (see Appendix B).

In summary, a prescriptive approach to competency standards can be adopted for technical/field personnel, where their competencies rely heavily on skills (Figure 1) that are easily described (e.g., Table 4) and will change little with time, but a more performance/outcome-based approach will be needed for design/engineering personnel, where experience will be more important (Figure 1).

7. Assessment, Award, and Certification of Competence

"… *[M]en and women who aspire to be recognized as professional engineers and technicians require independent assessment of their competence….*" [3].

"To be competent, individuals must provide evidence that they have the required experience, technical skills, knowledge, understanding and behavior to perform a job role/function and that they apply them consistently, safely and in accordance with relevant procedures and Standards…." [31].

7.1 Assessment

Candidates can be assessed against the competency standard. First, the assessment of a competency will require the candidate to provide evidence of competencies, achievement, and qualifications. This evidence is essential and should be tangible (e.g., examination results or references), rather than intangibles only (e.g., self-assessment [32]).

Where evidence is not sufficient, the candidate will require a formal assessment. The assessment should be conducted by comparing the required competencies for the job with those possessed by the candidate. Competency standards give the necessary detail of the competency and its level (Awareness to Expert). This allows a simple assessment against the standards.

The assessment should be conducted by a suitably qualified and independent body ("Assessment Body"). There are various methods of assessing competencies, including: Self-assessment, Performance, Examination, and Interview. The competency standard will recommend a suitable assessment method.

7.2 Award of Qualification

Candidates who pass this assessment can be awarded the competency as a "qualification" and can be presented with a Certificate recognizing this qualification by the Assessment Body.

7.3 Certification of Competence[5]

Candidates who pass the assessment are qualified in this competency (as they have been assessed and have tangible evidence).

Qualifications must be "portable": as personnel move jobs, the qualifications they obtain need to be recognized by all companies. A problem with "job" qualifications (e.g. [5, 33]) is that they are often studied for, and awarded by, companies. This means they are "self-certified": the pipeline companies organize the training and assessment of personnel. This leads to a problem with "portability": people move jobs often, and the qualification they bring with them into another company may not be recognized by the new company.

Portability is achieved by having the qualification "certified." This certification is conducted by an independent body, which

[5] There is often confusion over the terms "qualification" and "certification". Engineering standards ask for "qualified" personnel ("qualified" through training and/or experience) to produce the products to the required standard. Standards ask for these qualified personnel but never ask for "certified" personnel.
Companies often decide who is "qualified" by assessing their personnel's training and experience against their own processes and criteria. The customer must trust the companies' processes. These processes and criteria are documented, but they are not usually "certified" (a verification that the product, service, or system in question meets specific requirements). These "employer-based" qualifications will lead to a variety of criteria, inconsistency, and lack of credibility.
A better approach is for an independent third-party certification body to certify the qualification on the basis of a central certification standard or agreed processes and criteria.

certifies that the processes followed (including any assessments) meet the requirements of the competency standard and that the assessment and the award of the qualification have been audited and verified.

Hence, a qualification is a two-step process: award and certification [34, 35]. The certification should be conducted by an independent body.

8. "Shelf Life" of a Competency

Competencies do not last a lifetime. They have a time limit. A 3 to 5 year time limit is typically recommended for reassessment (e.g. [7, 36]) for both the competency standard and the individual. The actual time will depend on the competency, as some competencies change frequently (e.g. IT competencies).

The development of an individual's competence will last his/her lifetime, as it is a continuous learning process improving with experience, knowledge, and training. Individual competencies cannot be expected to improve throughout an individual's career: competency is related to a task, and if the task does not change, the required and appropriate competency will not change. However, processes, procedures, equipment, and technologies continually change with time, so it is essential that competencies are continuously assessed.

9. Case Study in Competency Assessment

The Competence Club (www.competence.rosen-group.com) is an organization that can advise on competence development, training, assessment, and certification. An engineer contacted the Competence Club and requested a competency assessment, as they wanted to be seen as a qualified pipeline integrity engineer. The individual wanted to show current and future employees that they were demonstrably competent in pipeline integrity and stated that they believed competency assessment would help their career. The engineer discussed their long-term career aspirations with the Competence Club, and a number of competencies and the required levels, aimed at being a demonstrably competent pipeline integrity engineer, were recommended using Reference 12. The first competencies assessed were:

Competency	Competence Level
Ethics and Responsibilities	Foundation
Hydraulics	Awareness
Pipeline Risk Management	Foundation
Failure Analysis	Foundation
Failure Modes and Mechanisms	Foundation

Competency standards were needed in these competencies. The competency standards were obtained from the Competence Club, which also provided the assessment procedure and managed the process from the request for assessment to the award of the qualification. The assessment and provision of the assessors (subject matter experts) were provided by the Qualification Panel for the Pipeline Industry (QPPI) (www.qualificationpanel.com).

The assessment process is summarized in Figure 3 and Table 5.

The assessment process is both easy and quick, but it requires a robust assessment procedure and the availability of a suitable subject matter expert. There are costs: the appointment of a subject matter expert can be expensive, and the procedure must be managed, logged, and audited.

The engineer passed their assessments, and continues to be assessed in other competencies to achieve their career goal of being demonstrably competent, with portable qualifications.

10. Discussion and Conclusions

10.1 Competence and Incompetence

Competence is the ability to perform a task to a specified level, and it is demonstrated by appropriate levels of training, knowledge, skill, and experience [37].

Demonstrable competence inspires confidence, and workers, managers, the general public, and regulators need this confidence. Lack of competence may lead to failure [38]; consequently, incompetence cannot be tolerated.

This is an important point: an organizational benefit of competence and its assessment is that it can identify incompetent people. Incompetent people cannot identify themselves: incompetent people tend to see themselves as more competent than they actually are, whereas more competent people tend to see themselves as less competent than they actually are [39]. This means we need to be extremely careful with incompetent people; they do not know they are incompetent [39]:

"… people who are unskilled… suffer a dual burden: not only do these people reach erroneous conclusions and make unfortunate choices, but their incompetence robs them of the metacognitive ability to realize it."

Beware of the incompetent, they can cause damage even when you think they cannot:

"The incompetent with nothing to do can still make a mess of it." (Laurence J. Peter)

10.2 Not Competent versus Incompetent

There is a difference between "not competent" and "incompetent": people who are not competent can be made competent by a structured learning program, but it is difficult to deal with incompetent people [12].

- "Not competent" means the individual recognizes a gap in a competency. There is hope for individuals who are not competent.
- "Incompetent" means an individual has a demonstrable inability in a competency. There is little hope for incompetent individuals.

The analogy is riding a horse. I will not attempt to ride a horse, as I know I am not competent to do it. The incompetent will get on the horse and fall off.

Then blame the horse….

10.3 Competency Standards

"Competency standards" provide a common definition of a competency, with its minimum requirements. Competencies can be assessed against these standards.

The contents of a competency standard should clearly state its purpose and outcomes and detail the knowledge, training (structured learning), mentoring (guided learning), and experience (self-learning) requirements, and an assessment method. Individuals who pass the assessment are qualified in this competency (as they have been assessed and have tangible evidence).

10.4 Competency Assessment

We demonstrate competence through assessment.

The value of competence is obvious, and it is required in standards and regulations; however, competency assessment is not usually (explicitly) required, so… why perform the assessment? The assessment can be costly, but it has many benefits [15]. The assessment:

- is tangible evidence of standards and regulatory compliance;
- inspires confidence in workers, managers, customers, the general public, and regulators;
- helps people with career development;
- helps with recruitment (replacing interviews based on CV evidence with competency-based evidence);
- can be used in an organization's personnel appraisal process; and,
- can be used as a quantitative basis for training requirements.

10.5 Competence and Behaviors

We should not forget human behavior in our competency assessment: both human error and inappropriate behavior have been linked to accidents [5, 40]. Employing competent individuals should break this link (Figure 1). This paper has not addressed human behavior, but it is a crucial consideration in competency assessment: behaviors and actions influence culture through attitudes and perceptions, with behaviors determining the performance of systems [40].

10.6 Prescriptive or Performance-based?

Competency standards can be either prescriptive or performance-based.

The choice between a prescriptive and performance-based standard depends on:

- the competency level (competencies of field technicians are easy to prescribe);
- the complexity of the competency;
- the homogeneity of the industry (an industry with few organizations, similar technologies, equipment, processes, etc. is homogeneous and suitable for prescription, but if the industry is heterogeneous, a more performance-based approach may be more appropriate); and
- the regulator's resources and capabilities to police the standard, where appropriate.

10.7 Portability of Qualifications

Qualifications must be "portable": as people move jobs, the qualifications they obtain need to be recognized by all companies.

Portability is achieved by having the qualification "certified." This certification is conducted by an independent body, which certifies that the processes followed (including any assessments) meet the requirements of the competency standard and that the assessment and the award of the qualification have been audited and verified. Hence, a qualification is a two-step process: award and certification.

10.8 Learning from Other Industries

We "learn from mistakes", and this can be a good thing: for example, the current US president has had six of his companies file for bankruptcy [41], and Harvard Business School says [42]: "*… failure is not always bad. In organizational life it is sometimes bad, sometimes inevitable, and sometimes even good*." Obviously, there are some jobs where failure is not an option or can be a deadly option; for example, in the military. There are also some industries where failure can be a deadly option; for example, the pipeline industry.

Can the pipeline industry learn from other "not an option" industries? A review [43] of "high-performance" teams, where failure can be deadly (for example, Special Weapons And Tactics teams and firefighting teams) concluded that having the right people is crucial, as is "*… a willingness to get rid of members who don't consistently deliver outstanding performance*." The message? Competent people in, incompetent people out.

10.9 Concluding Comment

Competence is a key element of safety. Safe operation of a pipeline relies on a complex mix of hardware, software, human factors, and safety management systems.

Materials, designs, and technical systems become more reliable every year, changing the focus on accidents to human causes: it is estimated that up to 80% of accidents may be attributed, at least in part, to the actions or omissions of people [44].

The pipeline industry has also seen the causes of its failures change with time, and personnel competence will be a key consideration as pipelines age [45]. The question is, *What is the industry doing about it*?

11. Acknowledgements

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TABLES AND FIGURES

Competence Level (characteristic)	Description	Knowledge	Supervision	Responsibility	Summary
Awareness (probation)	This level is for new or inexperienced individuals with no competencies and individuals (such as senior managers) who only want an "awareness" of a competency. These individuals can be considered in a "**probation"** or "**awareness"** period, where time is allowed for a job holder to demonstrate basic understanding of the job competencies but is not required to carry out work without close and continuous supervision in all of the tasks associated with the competency.				Can interpret and evaluate the knowledge and can both communicate it and present coherent arguments.
Foundation (knowledge)	Understanding of effects and consequences.	Knowledge and understanding of best practice.	Is able to carry out work **with supervision.**	The Practitioner/ Expert supervises their work.	Critical understanding and analysis of the knowledge and ability to **apply the knowledge.**
Practitioner (application)	Demonstrates competence to select the most appropriate options.	Aware of current developments, and has demonstrated experience, and can apply knowledge to new situations.	**No supervision required.**	Can supervise Foundation Level.	Able to self-manage, with a critical and systematic understanding of the knowledge, and can **make judgements and propose solutions.**
Expert (creation)	Breadth of experience and knowledge. Deep understanding of best practices.	Demonstrated managerial skills to undertake overall responsibility of a function, and can apply new knowledge to new situations and deliver solutions.	**Can train and assess others.**	Can supervise Practitioner Level.	A self-learner with a critical awareness of current and complex issues and best practices, and is able to do original work, deal with multiple problems, able to explain theoretical bases and weaknesses, and can propose new solutions. **A subject matter expert.**

Table 1. Competence Levels [1-9, 15].

Competence Level	**Characteristic** (these will overlap) [1]	**Example outcomes** (these will overlap and can be used in all levels where appropriate) [2,3,4]
Foundation	Knowledge [5] (remember, understand)	Can arrange, clarify, classify, compare, describe, define, discuss, distinguish, estimate, explain, express, extend, generalize, give examples, identify, infer, judge, locate, name, outline, predict, recognize, review, rewrite, restate, state, or summarize.
Practitioner	Application (analyze, apply)	Can analyze, apply, arrange, assemble, assess, break down, calculate, choose, compare, compute, conclude, contrast, criticize, debate defend, demonstrate, design, differentiate, discover, discriminate, distinguish, employ, formulate, illustrate, intervene, inspect, investigate, make an inventory, manipulate, modify, operate, practice, prepare, produce, propose, question, recommend, relate, schedule, show, solve, select, sketch, test, or use.
Expert	Creation (evaluate, create [6])	Can appraise, categorize, change, combine, compose, construct, create, develop, devise, elaborate, estimate, evaluate, improve, interpret, invent, judge, justify, measure, organize, predict, rate, rearrange, revise, rewrite, start, synthesize, tell, value, or write.

Notes:
[1] Based on Bloom's taxonomy [19].
[2] These "outcomes" are the learning outcomes expected from individuals achieving this level.
Outcomes must be "measurable"; therefore, when writing these outcomes, the use of words such as "appreciate," "know," or "understand" should be avoided, as they are vague and difficult to assess and measure. "Action" verbs such as "define," "apply," or "analyze" are better choices.
The outcome should have a "context": for example, how much supervision will be required, or how much information will be available, or how quickly will the skill be applied (slowly, quickly)? Accordingly, a "learning outcome" must have:

- an "active" verb to describe the behavior that can demonstrate the individual's learning; and
- information about the context for the demonstration.

[3] The higher the competence level, the more autonomy, unpredictability, novelty, and decision-making is expected.
[4] There will be overlap in descriptions of outcomes; for example, all engineers can critically analyze situations, but the context, available information, and resulting outcomes will differ with different levels of engineers.
[5] Able to recall and retrieve relevant knowledge from memory and understand the meanings.
[6] Able to put various learned elements together to form a coherent and functioning model or argument and able to reorganize these elements into a new pattern or structure.

Table 2. Competence Characteristics for Differing Competence Levels.

Competency number.	e.g. *"CS_010."*
Competency title.	e.g., *"Onshore Pipeline Design."*
Competency level.	e.g., "A*wareness, Foundation, Practitioner, or Expert."*
Competency description.	e.g., "*The underlying principles, concepts, and technical parameters in onshore pipeline design, giving the individual an all-round understanding of pipeline design processes."*
Competency purpose.	e.g., "G*ive the individual the ability to design oil and gas pipelines, using prescribed standards."*
Competency outcomes.	Knowledge, understanding, skills, etc., are summarized in "outcomes." "Outcomes" state what the holder should know, understand, value, or be able to do when they gain the competency (e.g., "*Can discuss pipeline design [front end engineering and detailed design] principles, standards and regulations, and can outline and summarize the bases of the key contents of design standards, including design for strength and fatigue."*).
Academic and professional qualifications.	The qualifications required to be considered before attempting to satisfy this standard; e.g. BSc or MSc, or CEng or PEng.
Pre-requisites.	The required knowledge or conditions that should be satisfied before being considered for this competency (e.g. other competencies). A pre-requisite is a recommendation before attempting the competency and may contribute to the competency being considered; for example, it may satisfy elements of the competency being taken.
Co-requisites.	A co-requisite is a recommendation that should be taken at the same time (e.g. other competencies). Co-requisites usually contain information needed to allow the specified competency to be achieved and may contribute to the competency being considered; for example, it may satisfy elements of the competency being taken.
Skills and knowledge elements of the competency.	Skills (e.g. "*Onshore pipeline design principles and processes"*).
	Knowledge (e.g.): • *Feasibility studies, conceptual design, front end engineering design, detailed design.* • *Permits and quality plans.* • *Environmental impact of pipelines.* • *Routing (land purchase, land rights).* • *Construction and testing in a variety of environments (rural, mountainous, swamps, etc.), crossings, and construction costs.* • *Selection and properties of pipeline bends, components, and installations.* • *Substance and location classification, proximity distances, design factors, safety factors, stress calculations (including thermal and external loads, and fatigue), and equivalent stresses.* • *Theory of pipeline sizing and wall thickness calculations.* • *Pressure testing.* • *Materials selection, including line pipe types, effect of mechanical properties, and corrosion allowance.* • *Pipeline coatings and cathodic protection*.
Training/mentoring [11] /experience recommended to gain competency.	Specify type and timeline.
Assessment method.	Self-assessment, examination, performance, interview, etc..
Reassessment interval (years) and method.	Usually 3 to 5 years.
Supervision.	Can the individual work on this competency with or without supervision?

Table 3. Typical Contents of a Competency Standard.

Task 0321	Valve Corrective Maintenance	
(a) Task guidance.	This task includes the repair, replacement, alteration, or refurbishment of valves, except valves for the temporary isolation of service lines and service discontinuance as addressed in Task 1191, Maintenance of Service Valves Upstream of Customer Meters.	
	1. Select task procedure(s) and appropriate equipment.	
	2. Verify valve identification, as applicable.	*(a)* Identify valve location. *(b)* Confirm valve position (open/closed). *(c)* Communicate with appropriate personnel, (operations, control center, customers, etc.).
	3. Perform valve corrective maintenance, as applicable.	*(a)* Repair or replace locking device. *(b)* Clean valve box. *(c)* Replace or adjust valve box. *(d)* Flush valve. *(e)* Set adjustments. *(f)* Replace or adjust packing or seals.
	4. Lubricate valve, as applicable.	
	5. Document, as required.	
(b) Potential applicability	Liquid, gas, and distribution pipelines.	
(c) Difficulty	4 (1 is low, 5 is high).	
(d) Importance	4 (1 is low, 5 is high).	
(e) Interval of evaluation	3 years.	
(f) Evaluation method	1. Initial: Performance evaluation or written or oral evaluation.	
	2. Subsequent: Written or oral evaluation.	
(g) Span of control	1:2 (this is the maximum number of non-qualified individuals that a qualified individual can direct and observe performing the task).	

Table 4. Example of Competency (“Task”) from ASME B31Q [5].

Step	Description	Action
1	Registration	The engineer **enrolled into the Competence Club's (CC) on-line learning portal**.
		The engineer was sent the relevant (five) **competency standards** and the detailed **assessment procedure** (which included the type of assessment to be conducted, examples of questions that could be asked, rules for the assessment, the process, and an appeals procedure) by the CC.
2	Self-assessment	The engineer performed a **self-assessment** (against the competency standards) and decided they were competent in the competencies and the levels specified.
3	Competency experience check	The engineer confirmed they were receiving **relevant experience in the competencies** (as specified in the competency standard) to be assessed.
4	Professional experience check	The engineer confirmed they had **relevant professional experience and qualifications**, therefore …
5	Professional experience assessment	No further **assessment of their general engineering knowledge** was necessary.
6	Preliminary competency assessment	The engineer confirmed they had the relevant skills, knowledge, and experience to satisfy the competency standards, and **a preliminary (on-line) competency assessment** was not needed.
7	Submission of evidence	**The engineer submitted their CV, including verified experience, to the Competence Club** and agreed to their assessment process.
		The documentation was checked by the Competence Club and then sent to the Qualification Panel (QP).
		The Qualification Panel appointed a subject matter expert (SME) to assess the documentation. The documentation showed that the individual should possess the necessary competencies and was a candidate for assessment.
8	Assessment	**Assessment (interview) dates were agreed between the SME and the engineer**. The assessment procedure was explained and would consist of an interview (over Skype), involving a number of technical questions to evaluate the five competencies.
		The engineer agreed with the appointment of the SME and agreed to the Qualification Panel assessment procedure. Note that this assessment process requires one SME for assessment of Foundation Level competencies but requires two SME for assessment of Practitioner or Expert Levels.
		The interviews/assessments were conducted, and the assessment procedure was strictly applied. The engineer was asked five questions in each competency, and the answers were noted and assessed. The assessment, questions asked, and responses were documented and filed by the Competence Club.
		The results of the interviews were assessed by the SME, and the SME awarded passes in all five competencies.
9	Qualified and Certified	**The engineer was informed by the Competence Club of the successful interviews and awarded qualifications** in four of the five competencies assessed ("Awareness" level competencies can be assessed, but no qualification is awarded). **The Qualification Panel certified the whole process.**

Table 5. Assessment Process.

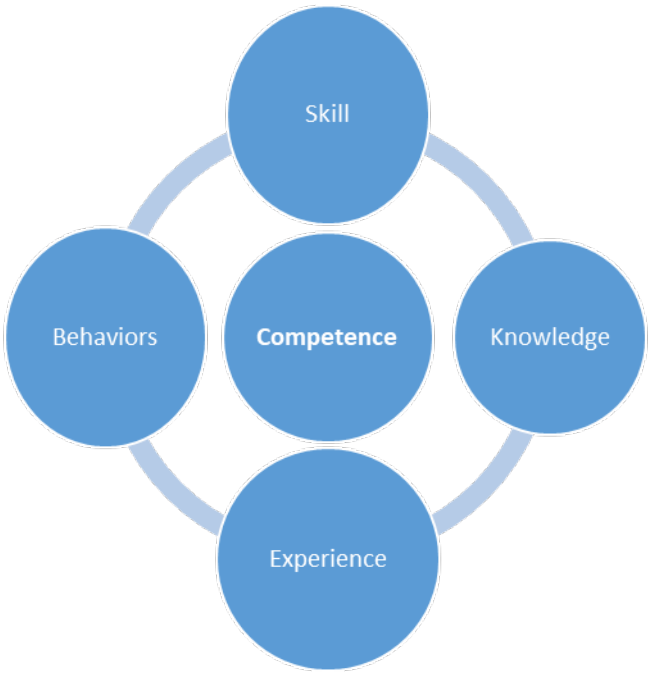

Figure 1. Competence Elements.

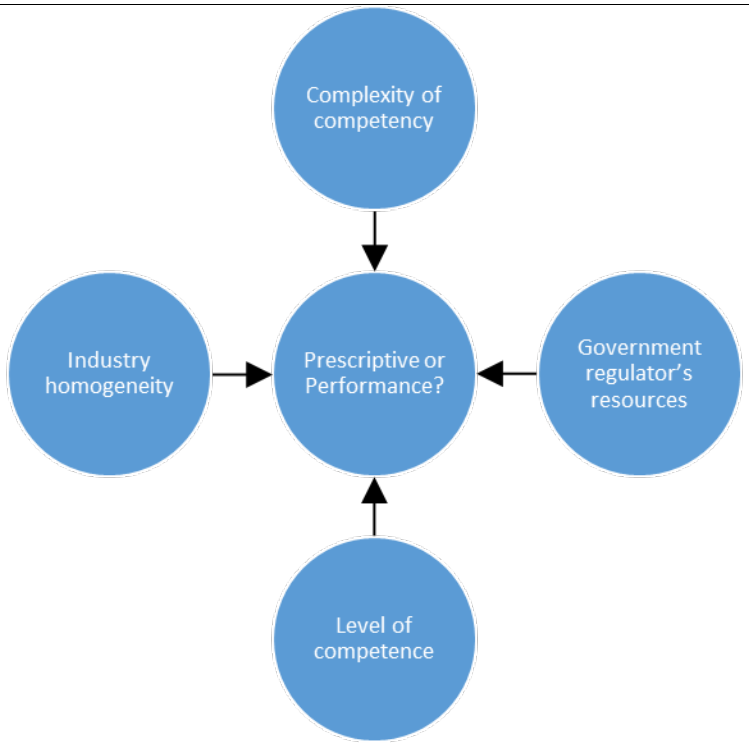

Figure 2. Choosing the Basis of a Standard.

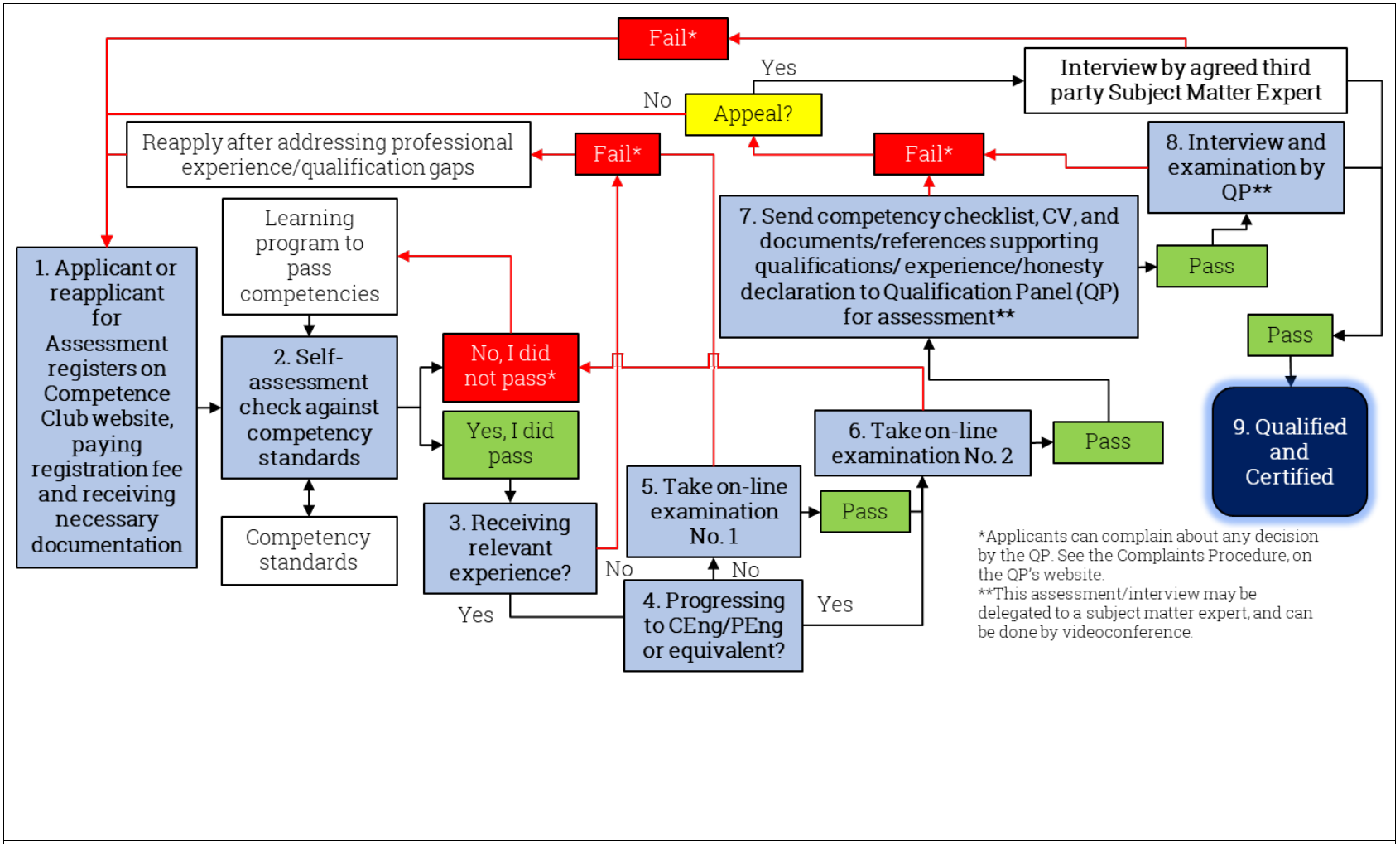

Figure 3. Competency Assessment Process used by the Competence Club.

APPENDIX A. Competency Standards' Terminology

1. **Ability**: Able to do a task (this is 'skill').

2. **Assessment**: '*An instrument or method used to measure learner attainment of intended learning outcomes (including but not limited to oral or written tests, skill demonstrations, portfolios, or work products)'*. [35]

   'Formative' assessment monitors an individual's learning to provide ongoing feedback that can be used by instructors to improve their teaching and by individuals to improve their learning. It contributes to learning through providing feedback. 'Summative' assessment is to evaluate an individual's learning at the end of a program by comparing it against some standard or benchmark; for example an end-of-program examination.

3. **Best practices:** 'Best practice' goes beyond 'good practice', and would be expected to be the best available practice, supported by other practices that give a measured and demonstrable improvement. Being 'the best' and 'best practices' are not the same thing. A 'best practice' may have been accepted by the profession or industry, but there may well be a better practice in existence somewhere in the world, which eventually will be accepted as the new best practice, but in the meantime, it is reasonable to continue with the existing best practice, and it is not necessary to search for this more novel best practice [46].

4. **Certificate:** '*document (letter, card, or other medium) awarded to certificate holders that designates the successful completion of a certificate program's requisites'.* [35].

5. **Competence**: A statement of desired knowledge, skills, and behaviours; therefore, competence is a combination of skills (ability to do a task), knowledge (ability to understand and explain the task), experience (type, years, supervision to obtain the knowledge), and behaviours, but a competency:

   - must meet an agreed standard;
   - must be updated as competencies can deteriorate, or become dated with time, leading to a drift into incompetency ('competency decay');
   - must be continually assessed, as evidence is needed that it is being absorbed by personnel ('demonstrable competencies'); and,
   - must be applicable under all working conditions.

6. **Competency standard**: Competencies of a job holder need to be assessed against a standard to ensure validation. 'Competency standards' provide a common definition of a competency, with its minimum requirements, and expected outcomes.

7. **Competent body**: A 'competent body' is an individual or group of individuals which can demonstrate appropriate knowledge, skills, and experience to perform the necessary assessments of the topic under consideration.

8. **Co-requisites**: A co-requisite is a requirement that should be taken at the same time. Co-requisites usually contain information needed to allow the specified competency to be achieved.

9. **Demonstrable**: Provide tangible evidence.

10. **Experience**: Work activity accomplished under the direction of qualified supervision, but excluding time spent in organized training programs [47]. It is self-learning under the supervision of a line manager. It indicates the workplace experience required to demonstrate competence. This will include years of experience, level of experience, and type of experience. Experience is the process of obtaining knowledge and skills from doing and/or participating in relevant projects, and the accumulation of knowledge and skills leads to a competency. This experience must be 'relevant': this means relating to this competency. A mentor is required to direct, monitor, check, and confirm this experience.

11. **Good practices:** 'Good practices' are practices, documents, and guidelines produced by: government departments; standards-making organisations (e.g. ISO, ASME, CEN); trade federations; professional institution; etc.. They are readily available, and recognised as current practice. They can be considered 'minimum' requirements.

12. **Knowledge**: Understanding gained through experience or study. Conversely, experience is the knowledge that comes from personal involvement. [14].

13. **Learning program**: Description of the training, mentoring, and relevant experience needed to gain a particular competence.

14. **Mentor**: A 'mentor' is a trusted adviser, with the necessary knowledge and wisdom to be a mentor. The mentor validates the competency and states that the competency outcomes have been met. This requires mentoring for the duration of the competency. It is recognized that personnel may not have access to a mentor, or not have a mentoring record for parts of their career; therefore, the mentoring requirement is less than the relevant experience requirement in the competency standards.

15. **Mentoring**: 'Mentoring' is advice and direction given to personnel, or 'guided learning'.

16. **Outcome**: A (learning) outcome identifies what the candidate knows and is able to do, or, will know, and be able to do by the end of a course or programme. The outcomes are measurable, and are used in assessing candidates. ASTM E2629-15 [35] considers a learning outcome as a '*statement of what learners are expected to know or be able to do as a result of the certificate program's learning event or program (recognizing that actual learning outcomes may or may not be those intended)*'.

17. **Pre-requisites:** The required knowledge or conditions that should be satisfied before being considered for this competency. A pre-requisite is a requirement that should be met before you attempt this competency.

18. **Qualification** [48]: An official record or document (such as a certificate or diploma) which shows a person has completed a course of study or training and is qualified to practice a profession or activity. A qualification is expressed in a formal document (e.g., a certificate,

degree, diploma, or award).
According to the European Commission [18] a qualification is '*a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to a given standard*'.
Qualifications for technicians/operators can be considered 'occupational' and provide a standard usually in the form of a list of competencies ('vocational' skills), corresponding to the main tasks and functions of an occupation. These qualifications/standards differ from qualifications/standards in education where the focus is on what people need to learn, how they will learn it, and how the quality and content of learning will be assessed. In educational qualifications/standards, the competencies are organised in learning fields (or teaching units), following the logic of progressive accumulation of knowledge and skills: the aim is to steer the learning process.
These differences are necessary as some competencies required in the workplace are beyond the scope of educational and assessment processes.

19. **Qualified** [5]: An individual that has been evaluated and can perform assigned tasks.

20. **Skill:** What you can do. An ability to perform a given task well, arising from talent, training or practice. [5, 14]. A demonstrable competency [49].

21. **Subject matter expert** [50]**:** An individual recognised as having a special skill or specialised knowledge of a process in a particular field, or of a piece of equipment. The SME must have demonstrable: talent; education (study); training; and, practice/experience. It is likely that a subject matter expert will need at least 10 years of relevant experience [37, 51], although some caution is needed with older engineers: *'Old-timers have the wisdom... but are at risk if they don't keep up with the scientific and technical knowledge of the profession*.' [40].

22. **Supervision**: Ability to manage workers with specified skills and/or understanding.

23. **Training:** An educational or instructional process (e.g., classroom, computer-based, or on-the-job) [13] by which an individual's knowledge, skills, and his/her capacity to do or act, physically and/or mentally, are improved [49]. It is the act of developing a particular skill, or type of behaviour, through demonstration, instruction and practice [52]. It is instructing individuals using materials designed to convey the skills and knowledge necessary to perform a particular task [5]. Training is 'structured learning', as opposed to 'guided learning'.

24. **Trainer:** An individual with the ability to train individuals with specified abilities and/or understanding, and/or supervisory abilities. ASME B31Q [5] states that the trainer must have demonstrated knowledge of the subject matter; for example: the individual is a 'Subject Matter Expert' [50]; or, he/she meets the education, experience, and training requirements to be qualified for the skill; or, possesses the knowledge, skill, and ability to provide the training using the selected training materials.

25. **Understanding:** Able to understand and explain the task (this is 'knowledge').

Appendix B. Example of a Competency Standard.

Competency Title	**Onshore Pipeline Design**
Competency Number	010
Document Revision	Rev B 2017

Competence Level (see Table 1)

	Awareness	**Foundation**	**Practitioner**	**Expert [50]**
Competency Description/Purpose	The underlying principles, concepts, and technical parameters in onshore pipeline design, giving the individual an all-round understanding of pipeline design processes.			
Competency Outcomes	Is **aware** of pipeline design (front end engineering, and detailed design) principles, standards and regulations, and **understands** the bases of the key contents of design standards including design for strength and fatigue.	Can **discuss** pipeline design (front end engineering, and detailed design) principles, standards and regulations, and can **outline** and **summarise** the bases of the key contents of design standards including design for strength and fatigue.	Can **perform** pipeline design (front end engineering, and detailed design), and **understands** differing standards, and can **apply** and **employ** the key contents of design standards, including valves, crossings, bends, temperature effects, geo-technics, environmental impact, and fracture control.	Can **teach** pipeline design (front end engineering, and detailed design), and **choose** between differing standards and regulations, and can **justify** the bases of the key contents of design standards.
Qualifications (e.g., academic or professional)	None.	Progressing or completed CEng or PEng or equivalent (e.g., 'engineer in training' program).	CEng or PEng or equivalent.	CEng or PEng or equivalent.
Pre-requisites	None.	Completed Awareness Level in this competency. [Competency standard then specifies any other 'Awareness' level competencies as pre-requisites]	Completed Foundation Level in this competency. [Competency standard then any specifies 'Foundation' level competences or 'Awareness' competencies as pre-requisites]	Completed Practitioner Level in this competency. [Competency standard then specifies any Awareness/Foundation/Practitioner level competencies as pre-requisites]
sites	[Competency standard specifies other 'Awareness' level competencies as pre-requisites]	[Competency standard then specifies any other 'Awareness' level competencies as co-requisites]	[Competency standard then specifies any 'Foundation' level competencies or 'Awareness' competencies as co-requisites]	[Competency standard then specifies any Awareness/Foundation/Practitioner level competencies as co-requisites]
ion available?	No ('Awareness' levels are not certified).	Yes.	Yes.	Yes.

Competency Elements ('Tasks') and Assessment

Skills (ability to do a task)	None	Onshore pipeline design principles and processes.	Can contribute to the design of a pipeline using standards, design tools/software, and recognised best practices.	Teach the competency.
Knowledge (understanding the task)	The history of pipelines, and pipeline standards, laws and regulations.	Feasibility studies, conceptual design, front end engineering design, detailed design.	Procurement practices.	Expert witness skills (giving evidence, writing reports, answering questions, preparing for Court).
	Planning, and economics of a pipeline.	Permits and quality plans.	Pipeline route selection considering legislation, risk, and interface with compressors, installations, fittings, crossings, terrain, environment, and end users.	Able to participate in industry working groups, or standard committees.
	Stakeholders in a pipeline operation.	Environmental impact of pipelines.	Block valve spacing.	
	Line pipe, bends, components, and installations.	Routeing (land purchase, land rights).	Pipeline hydraulics, over-pressures, and protective devices.	
	Routeing (with beneficial features and constraints).	Construction and testing in a variety of environments (rural, mountainous, swamps, etc.), crossings, and construction costs.	Fracture control.	
	Construction and testing (in a rural environment).	Selection and properties of pipeline bends, components, and installations.	Pipeline protection against damage, theft, and sabotage.	
	Operation.	Substance and location classification, proximity distances, design factor, safety factors, stress calculations (including thermal and external loads, and fatigue), and equivalent stresses.	Theoretical bases of onshore pipeline design, and best practices in onshore pipeline design.	
	Inspection and surveillance.	Theory of pipeline sizing and wall thickness calculations.	Slurry pipelines.	
	Decommissioning.	Pressure testing.	Geotechnics.	
	Pipeline safety, and safety record.	Materials selection, including line pipe types, effect of mechanical properties, and corrosion allowance.		
		Pipeline coatings and cathodic protection.		
Supervising and/or training	None.	None.	Supervisor for this competency.	Trainer for this competency.
Assessment	Quizzes (self-marked).	Summative.	Formative and Interview.	Formative and Interview.

Mentoring and Experience Requirements

Training	~2 hours	~18 hours	0	0
Mentoring (guided learning under the guidance of a mentor) [11]	~4 hours	~36 hours	Practitioners need 3 to 5 years mentoring to be proficient at a competency.	Experts need ≥5 years mentoring to be expert at a competency.
Experience (self-learning under the supervision of a	~14 hours	~100 hours	Practitioners need 5 to 7 years relevant experience to be proficient at	Experts need ≥10 years relevant

line manager)			a competency.	experience to be expert at a competency [37, 51]

Learning Program

The learning program describes in detail the purpose and outcome of this competency, and gives a detailed breakdown of training (type, and presentation platforms), mentoring and experience requirements. The program also gives timelines, trainer/mentor qualification requirements, and more detail on assessment criteria.

The learning program is detailed in another document, and aims to satisfy all the stated outcomes in this Competency Standard, and address all the Competency Elements, Mentoring and Experience requirements.