The Evolution of Competency Certification in the Pipeline Industry – The Pipeline Integrity Engineer

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Abstract

The pipeline industry has long recognized the critical importance of establishing competency and qualification standards to ensure the safety, reliability, and integrity of pipeline operations. The journey toward internationally accredited certifications began by addressing the limitations of traditional competency measures, such as IQ tests and personality assessments. Instead, the focus shifted to developing competency-based frameworks specifically tailored to the pipeline industry, emphasizing the ability to perform tasks to a recognized standard and the need for practical, job-specific qualifications. This foundational phase established key competency elements and standards, guided by international standards like ISO 13623 and ASME codes, ensuring that qualified and competent personnel are engaged across all stages of pipeline activities.

The journey then progressed into the development and implementation of a structured certification process. This phase was marked by creating a qualification 'route map' that integrated competency-based learning programs with objective assessments. Extensive collaboration with industry experts led to the development of robust learning guides and digital learning platforms that facilitated knowledge transfer and continuous professional development. Rigorous competency assessments were also introduced to ensure that the certifications awarded reflected genuine expertise and aligned with industry standards.

The culmination of these efforts was achieving international ANAB accreditation for pipeline integrity certifications. This milestone marked the successful transition from theory to practice, establishing a new global standard for pipeline competency certifications. The widespread implementation of eight ANAB-accredited certifications in critical areas of pipeline integrity management has set a new benchmark for the industry, providing a clear and structured path for professionals to achieve and demonstrate their competency.

This paper showcases the evolution of competency certification in the pipeline industry, underscoring its transformation from concept to a robust, globally recognized standard that ensures the highest levels of safety and expertise in pipeline operations.

A Holistic Approach to Engineering Competency

In the 1960s, American psychologist David McClelland demonstrated that traditional IQ tests and personality assessments were poor predictors of job competency [1]. He advocated for hiring based on demonstrated competencies in relevant fields. Simple tests and behavioral assessments are insufficient to gauge true competency since many competencies are not visible and are deeply ingrained in the individual [2].

Since the 1980s [3], competency standards have been widely adopted to improve both company and staff performance. Competency encompasses the skills and behaviors needed to perform a job well.

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It involves undertaking responsibilities and performing activities to a recognized standard regularly, using a combination of practical and thinking skills, experience, and knowledge [4, 5]. Competence develops over time through formal qualifications, training, on-the-job learning, instruction, and assessment [6, 7]. Technical competencies alone are not enough [8]; behaviors, such as attitude, physical ability, and values, also need to be addressed.

Confidence can be mistaken for competence; over-confident but incompetent individuals can lead to an organization being unaware of its limitations [9]. Over-confident staff should be challenged, and their confidence must be supported by evidence-based competency and factual claims.

The Engineering Council in the UK [10] and the pipeline association UKOPA [11] support a holistic view of competency, stating that professional competence integrates knowledge, understanding, skills, and values, and goes beyond performing specific tasks. A pipeline engineer is deemed competent if they possess the necessary theoretical and practical knowledge and sufficient experience to perform work safely.

Nowadays, the development of competency-based frameworks is increasingly important. There has been a significant shift towards task-based qualifications and industry-specific standards. International regulations, such as ISO 13623 and ASME codes, play a crucial role in shaping the development of these competencies.

Establishing Comprehensive Competency Standards

In the absence of defined competency standards, a Competency Standards Manual [15] was developed. This manual detailed core competencies for pipeline professionals (e.g., integrity management, safety management, technical expertise) within a structured framework. Each competency standard aligned with global regulations, including ISO 13623 (pipeline integrity) and ASME codes (design and construction). The result was a manual that was, and still is, applicable across all pipeline operations stages—from design and construction to operation and decommissioning.

A job-holder's competencies must be assessed against defined standards to ensure validation [12]. These standards provide a common definition of a competency, with minimum requirements. Appendix A shows a simple prescriptive standard for field technician however, competency standards for professional staff may need to be more 'performance' based, or 'goal-based'. Prescriptive standards are clear and easy to communicate but inflexible and require constant updates. In contrast, 'performance' or 'goal-based' standards offer more flexibility but can introduce ambiguity regarding compliance requirements [13].

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Competency standards should remain simple, measurable, and auditable, detailing outcomes—what the job holder will be able to do in measurable ways [7, 14,15]. Outcomes should be clear, allowing assessment and cover [16]:

- Ability (skill): ability to perform a task.
- Understanding (knowledge): ability to understand and explain the task.
- Supervision: ability to manage staff.
- Training: ability to train staff.

Subject matter experts (SMEs) [17] write competency standards. SMEs possess specialist skills, knowledge, and experience in their fields, continuously learn, and have their expertise recognized by peers, adding credibility [18].

For further details, see Appendix B on key elements of competency standards. A simple approach to writing competency standards ensures easy adoption; for example, limiting descriptions to a single sentence [14].

Creating Competency Roadmaps for the Pipeline Industry

Due to the lack of clear process and definition for competency, a route map was created to help operators demonstrate their employees' competencies. This introduced a structured qualification process combining competency-based learning and objective assessments.

Pipeline industry standards, such as the Canadian pipeline standard Z662 [19], define 'competent' staff as qualified, trained, and experienced to perform required duties. Regulations emphasize [6] that competent staff must have sufficient knowledge of tasks, understand associated risks, and recognize their limitations. Competencies must also be demonstrable, supported by tangible evidence. This is supported by major incidents, which have shown that a lack of certain skills or knowledge can lead to errors [20].

As the industry relies more on multitasking and downsizing, staff must take on broader responsibilities with less supervision, increasing the need for validated competence. This requires changes in hiring practices and ensuring staff have the correct qualifications.

The competency roadmap comprises [15]:

- Qualification: Starting with a 'qualification descriptor' detailing requirements, expectations, and how to achieve the qualification.
- Competency Standard: Fully describing each competency, its minimum requirements, elements, and how it is obtained (training, experience, etc.).
- Assessment: Assessing each competency (e.g., by examination) against specified criteria.

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- Learning Program: Detailing training, mentoring, and experience requirements to gain each competency.
- Certification: Certifying the qualification process by an independent body[1], resulting in a certified and verified qualification with demonstrable competencies.

The Job-Specific Qualifications

Job specifications typically outline essential and desirable competencies but often lack standardization and details on how competencies are demonstrated. Competencies are often ad hoc and assessed by interview panels. Qualifications are formal outcomes of assessment and validation processes, and there are three types: academic, professional, and job specific. However, academic qualifications may not address the continuous need for new skills, and professional qualifications are usually generic [22].

Job-specific qualifications are not always assessed or certified by a competent body, and their importance can change over time. A combination of qualifications is necessary for staff competence, which may take over 10 years to achieve [21]. When the qualifications are assessed by an independent body, they become a certification.

Evaluating Employee Competence: A Structured Approach

An individual's competence cannot be solely based on their personal assessment; it must be independently evaluated [22]. Various methods, such as self-assessment, performance assessment, examinations, and interviews, are used to assess competencies through written, oral, practical, or observational means [7]. The assessment process must be secure, well-specified, and designed to ensure the validity and comparability of results.

- Self-assessment: Staff can initially self-assess and then compare their assessment with their manager or subject matter expert. However, caution is needed as people may inaccurately assess their own competencies.
- Observational assessment: Conducted by a supervisor or trainer, often over a long period, which may be impractical. A 360-degree assessment involves evaluations by colleagues at various levels.
- Assessment by training: Training alone does not guarantee competence; it needs to be assessed, often through examinations, to confirm its value.
- Interview: Useful for confirming competencies and identifying gaps, involving technical questions relevant to the competency.
- Evidence-based assessment: Competency assessments should be based on measurable, clear evidence, and follow specific criteria.

[1] The Independent body overseeing this program is The Qualification Panel for the Pipeline Industry (https://www.qualificationpanel.com/).

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Resistance to assessment in industry often arises due to a lack of perceived value and the unfamiliarity with post-training assessments. Industry professionals, especially long-time employees, may resist assessments.

Considering these challenges, a Competence Assessment Procedure was developed in collaboration with industry experts [23]:

1. Know competencies and levels: Employees must understand the required competencies and their levels, typically specified in job descriptions or performance appraisals.
2. Assess competencies: Evaluate against a competency standard, which defines required skills, knowledge, and experience. Meeting the standard may result in a qualification.
3. Provide evidence: Compile tangible evidence, such as examination results or references, to meet competency standards.
4. Find an assessor: Use a qualified, independent assessor or assessment body for a formal, recorded evaluation. Self-certification is not widely recognized.
5. Conduct assessment: If evidence is insufficient, a formal assessment compares required competencies with those of the candidate, guided by competency standards.
6. Award certification: Successful candidates are awarded a certification by the assessor or assessment body, with independent bodies providing the highest credibility.

This procedure was then developed further into a formal, industry recognized certification process, against ISO17024 certification of personnel and was accredited by the ANAB (ANSI National Accreditation Board). Further details are given in Achieving International Accreditation.

Competency Development in Practice

The competence development process and content evolved in collaboration with industry operators [24]. These key partnerships with industry experts have helped to shape learning guides and digital platforms. This industry collaboration has ensured that certifications reflect practical, real-world skills.

A North American Company [24] identified the need to enhance fracture mechanics skills within their pipeline integrity teams and enrolled nine staff in a learning program, first cohort completed in 2020, two more added to date. The program combined active and passive learning methods, culminating in assessments. The strategy included encouraging active learning, such as case studies and reading relevant materials, supported by e-learning and on-demand videos.

Practical activities and specialized materials helped transfer acquired knowledge into practice. The subject matter expert provided mentoring, including live online sessions for discussion and questions.

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Observations from the Manager:

- A team-based approach fostered a complete learning environment and internal collaboration.
- Participation in group sessions was consistent despite day-to-day workloads.
- No formal criteria were set for program participation, but individuals with interest and initiative were selected.
- A checklist for self-directed activities improved engagement.
- Five of nine participants underwent assessment, with mini-assessments helping maintain engagement.
- A formal approach to competency is essential, especially with regulatory changes like the 'Mega Rule.'
- In-house experts continuously improve processes and knowledge to meet industry demands.
- The program was valuable and recommended for developing fracture mechanics competency.
- Training is just a part of competency development; mentoring and continuous learning are crucial.
- Remote learning environments offer flexibility and are effective in the current hybrid work model.
- New hires are expected to actively engage in training and professional development.

A South American company [24] engaged in a 4-year learning program, focusing on foundational competencies in pipeline integrity. Despite having an experienced team, the company participated in this program to trial and contribute to competency development efforts. The company emphasized the importance of post-training examinations to ensure comprehensive understanding.

Observations from the Manager:

- Availability and flexibility of courses allowed for 'learning while working.'
- Certifications, particularly those associated with the ANAB, were highly valued.
- The program focused on foundational competency levels, with staff progressing to higher levels.
- Long-term mentoring by senior staff was crucial for effective learning in junior staff.
- The incorporation of process safety and API 1173 references was recommended.
- The competency courses are now integrated into the company's training processes, with recommendations for broader adoption due to their comprehensive nature.

The validation of the project on real operators needs proved valuable, applying all the original design, and receiving comprehensive feedback on the process. The competence development process is validated and both companies continue to use the framework.

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Achieving International Accreditation

In 2024, global recognition was obtained through ANAB (ANSI National Accreditation Board) accreditation for pipeline integrity certifications. The ANAB accreditation establishes a new benchmark for pipeline competency standards globally and ensures that certifications are recognized across regions and industries. Through this qualification route map, competency development procedure, industry-relevant learning programs and accredited certifications, pipeline professionals now have a clear and structured pathway for career development. This has a wider impact on industry in areas such as reducing safety incidents and improving operational efficiency.

Content of the ANAB certifications

The eight ANAB-accredited certifications [25,26] for critical pipeline integrity roles are:

1. Pipeline Engineering Principles (CS001F): Certified individuals can describe pipeline-engineering principles, discuss best practices, and explain their bases.
2. Pipeline Inspection and Surveillance (CS005F): Certified individuals can describe differing pipeline inspection and surveillance methods and compare the best methods.
3. Pipeline Integrity Management (CS014F): Certified individuals can define, and distinguish between, differing integrity management methods/techniques, particularly pipeline integrity management and systems, and can list the threats to pipeline safety, and the consequences of pipeline failure.
4. Pipeline Defect Assessment (CS020F): Certified individuals can describe pipeline integrity and pipeline defect assessments (for all types of defects found in pipelines) and can summarize and give examples of fatigue assessment.
5. In-Line Inspection Technologies & Procedures (CS022F): Certified individuals can classify and summarize ILI technologies and procedures.
6. In-Line Inspection Data Analysis & Reporting (CS026F): Certified individuals can explain ILI data analysis and reporting procedures.
7. Stress Analysis (CS030F): Certified individuals can describe and review pipeline stress analyses.
8. Fracture Mechanics (CS032F): Certified individuals can explain the history of fracture mechanics, its principles, models (elastic, elastic-plastic, and plastic), and differing models, defining the best assessment methods using fracture mechanics. Additionally, they can define and distinguish between the fracture mechanics and traditional approach to fatigue assessment.

About the ANAB accredited certifications

Accreditation is a process through which an organization demonstrates that it adheres to defined criteria and guidelines, ensuring it operates effectively, efficiently, and in compliance with

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international standards. An ANAB accreditation signifies that the certifying body has proven that its certification program adheres to the ISO standard, verifying the integrity and quality of the certification process. This process bestows credibility to the private certification program, affirming that it meets the same benchmarks as those established by a standard certification program.

The road to achieving accreditation for each certification is a complex and methodical process. Delaying the large-scale rollout of the program until achieving accreditation for all core competencies was strategic, ensuring a quality program. The accreditation process involved thorough evaluation and feedback, whereby best practices were incorporated and a comprehensive, high standard program was delivered.

Accredited certifications, while not specifically required for pipeline operators, can significantly contribute to enhancing professional competence and expertise. These certifications offer deeper insights and advanced knowledge in specific areas, thereby improving understanding and the ability to apply concepts effectively in one's current role. Furthermore, certifications often encompass related topics or present diverse perspectives on the same subject, ultimately fostering a more comprehensive skill set, e.g. a certification in Pipeline Defect Assessments confirms knowledge applicable to a variety of inspection tasks.

There are four key elements required for accreditation: impartiality, competence, fair, transparent procedures and consistent, reliable processes, all of which must be supported by documented evidence. Section 8.4.b of the ISO/IEC 17024 [27] standard states subject matter experts must be involved in the development and review of the certification. Additionally, it must "fairly represents the interests of all parties significantly concerned…". To ensure the certification program met this stipulation, seventy subject matter experts from eight different countries were engaged in the program development, see Appendix C. This diverse involvement guaranteed a broader perspective and enhanced the relevance of the approach. Furthermore, the early adopters of the certification were selected to ensure diverse global representation, see Appendix D.

It is important to note that accreditation is not a one-time achievement; it extends beyond the initial approval process. Annual surveillance audits are required to verify that the stringent standards are consistently upheld. Additionally, organizations are obligated to perform regular updates through a Job Task Analysis survey, which acts as a framework for the competency assessment via examinations. This process effectively captures and defines the continuously evolving nature of the industry, outlining the current knowledge, skills, and abilities (KSAs) that professionals within the pipeline industry should be competent in, emphasizing the importance of fostering competency development.

Just as the Job Task Analysis reflects the evolution of the oil and gas industry, it is essential for emerging engineers and seasoned professionals to engage in continuous learning for them to remain relevant and effective in their positions. Investing in skill enhancement ensures that emerging engineers are well-equipped to meet the demands of their role.

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Those who completed awareness level learning prior to their certification exam, scored 3% higher than those who did not. Furthermore, those who completed an advanced course prior to their assessment achieved an average score that was 7% higher than those who did not engage in any preparation, see Appendix E. Additionally, 65% of those who passed the certification exam had completed an advanced course in Fracture Mechanics before taking the assessment, while 64% of those who did not take the advanced course failed the exam, see Appendix F.

Competency development for senior engineers is equally as crucial to an organization. It supports leadership development, enhances team performance, aligns skills with organizational goals, improves employee engagement, mitigates risks, aids succession planning, fosters innovation, ensures accountability, and provides a competitive advantage.

Online Learning makes Competence Development Accessible to All

Competence, education, training, knowledge, and experience are essential prerequisites, and these now need to be delivered in an increasingly virtual world with volatile market dynamics and evolving staff expectations. Fortunately, online learning and virtual competence development are available [28].

There has been a shift in the industry towards virtual working, which has been reflected in competence development through the investment in online learning environments and virtual engagements to support pipeline professionals.

Many online platforms provide the necessary tools, content, and resources for learners to enhance their knowledge and competencies. ROSEN's Competence Club is one such platform, developed for secure online training delivery. It boasts nearly 5000 members from 90 countries, with significant participation from the USA and UK, reflecting the growing interest in online learning [28].

The platform supports individuals and organizations in accessing learning programs and guides for certification and accreditation. Analysis shows a significant increase in member enrolments starting in March 2020 [28], coinciding with the global shift to remote working due to COVID-19, and this trend has continued: even after COVID, we are still learning and working online.

AI vs Engineers

With the rise of AI in society, the performance of AI versus human engineers in competency development exams has been explored and tested. A comparative study [29] was conducted involving 40 pipeline integrity engineers globally to benchmark the competence of engineers against AI tools in pipeline integrity.

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The study focused on five out of the eight subjects included in the Pipeline Integrity Engineer Qualification at the Foundation Level:

- Pipeline Engineering Principles
- Pipeline Integrity Management
- Pipeline Defect Assessment
- Inline Inspection Technologies and Procedures
- Fracture Mechanics

The participants included three types of AI bots and human engineers:

- Blind Bot: No prior topic training.
- Informed Bot: Access to only information about the exam topic.
- Trained Bot: Access to all verified training materials across all topics.
- Beta Testers (Human Engineers): Access to all materials similar to the Trained Bot.

Engineers, as expected, exhibited a wide distribution of scores, ranging from very high to very low. The assessment highlighted individual staff capabilities, providing valuable insights into their performance. In contrast, AI bots generated narrow distributions of scores, indicating they cannot yet match the top performers among human engineers.

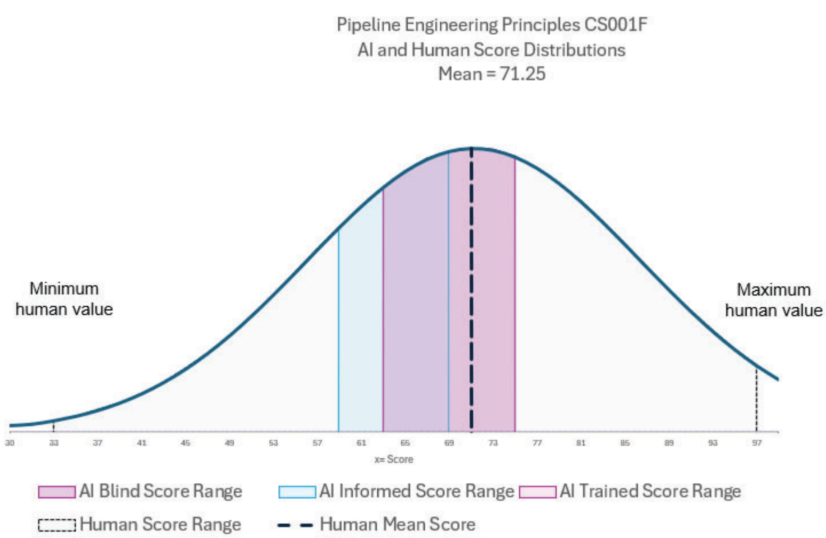

Figure 1. Pipeline Engineering Principles CS001F AI and Human Score Distributions.

AI bots struggled with poorly designed questions, particularly those with ambiguous wording or multiple correct answers. Bots performed better with text-heavy content but had difficulties with graphs and video transcripts. Training for new engineers often lacks narration, posing challenges for both bots and engineers. On questions related to pipeline standards and operations, AI bots scored significantly lower than human engineers, achieving only 16% compared to 83% for engineers. Additionally, bots found it challenging to process formats like flow diagrams, matrices, or simple questionnaires requested by some research organisations.

Hiring an AI bot results in an average worker with no comparison to human performance. For exceptional performance, hiring a human engineer remains the best option.

Closing Remarks

These competency development initiatives have significantly advanced the pipeline industry's standards and practices. From addressing the inadequacies of traditional measures to establishing comprehensive competency frameworks, efforts have ensured that pipeline operations are conducted by well-qualified and competent personnel.

The case studies from North America and South America illustrate the practical application and benefits of these competency development programs, highlighting the importance of continuous learning, structured assessments, and the integration of digital learning platforms.

The development of a structured certification process and the attainment of international accreditation, such as ANAB, has set a new global benchmark, providing clear pathways for professionals to demonstrate their expertise.

As the industry evolves with the rise of AI, comparative studies indicate that while AI can assist in certain areas, human engineers remain indispensable for their ability to excel in complex, context-specific tasks. The emphasis on evidence-based assessments, alignment with international standards, and the strategic incorporation of feedback ensures that certification programs remain at the forefront of competency development ensuring that the pipeline industry can meet current and future challenges with a highly skilled and competent workforce.

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Appendix A

Example of a competency standard (task) from ASME B31Q [13].

<table>
<tr><th>Task 0321</th><th colspan="2">Valve Corrective Maintenance</th></tr>
<tr><td rowspan="6">(a) Task Guidance.</td><td colspan="2">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.</td></tr>
<tr><td colspan="2">1. Select task procedure(s) and appropriate equipment.</td></tr>
<tr><td>2. Verify valve identification, as applicable.</td><td>(a) Identify valve location.
(b) Confirm valve position (open/closed).
(c) Communicate with appropriate personnel, (operations, control center, customers, etc.).</td></tr>
<tr><td>3. Perform valve corrective maintenance, as applicable.</td><td>(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.</td></tr>
<tr><td colspan="2">4. Lubricate valve, as applicable.</td></tr>
<tr><td colspan="2">5. Document, as required.</td></tr>
<tr><td>(b) Potential applicability</td><td colspan="2">Liquid, gas, and distribution pipelines.</td></tr>
<tr><td>(c) Difficulty</td><td colspan="2">4 (1 is low, 5 is high).</td></tr>
<tr><td>(d) Importance</td><td colspan="2">4 (1 is low, 5 is high).</td></tr>
<tr><td>(e) Interval of evaluation</td><td colspan="2">3 years.</td></tr>
<tr><td rowspan="2">(f) Evaluation method</td><td colspan="2">1. Initial: Performance evaluation or written or oral evaluation.</td></tr>
<tr><td colspan="2">2. Subsequent: Written or oral evaluation.</td></tr>
<tr><td>(g) Span of control</td><td colspan="2">1:2 (this is the maximum number of non-qualified individuals that a qualified individual can direct and observe performing the task).</td></tr>
</table>

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Appendix B

Pro-forma showing key elements of a competency standard [12].

Competency number	
Competency title	
Competency level	e.g., 'Awareness, Foundation, Practitioner, or Expert'.
Competence description	
Competence purpose	
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. Outcomes are the goals rather than the process/path to arrive at them.
Academic and professional qualifications	The qualifications required to be considered before attempting to satisfy this standard; e.g., BSc or MSc, 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 elements of the competency	What you can do when you have this competency. List the skills elements needs for this competence.
Knowledge elements of the competency	Understanding gained through experience or study. List the knowledge elements needs for this competence.
Training recommended to gain competency	Education or training (e.g., classroom, computer-based, or on-the-job). Specify type, and timeline.
Mentoring recommended to gain competency	Guided learning under the guidance of a mentor. Specify type, and timeline.
Experience recommended to gain competency	Self-learning under the supervision of a line manager. Specify type, and timeline.
Assessment method	Self-assessment, examination, performance, interview, etc..
Assessment body, and status	Independent or dependent?
Reassessment interval (years), and method	Typically 3 to 5 years.
Supervision	Can the individual work on this competency with or without supervision? Can the individual supervise staff on lesser competency levels?

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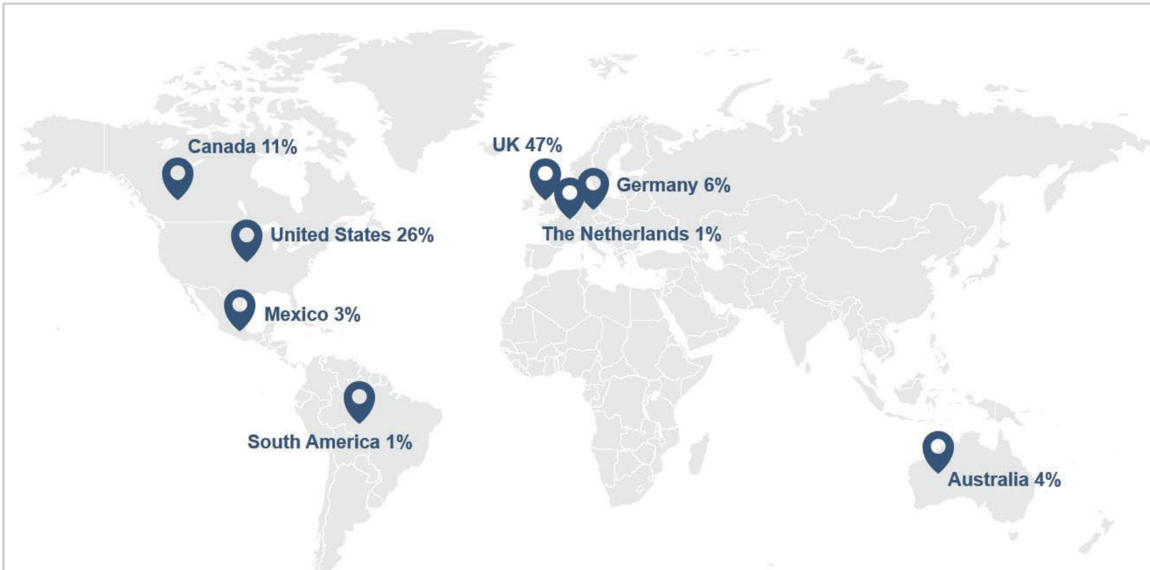
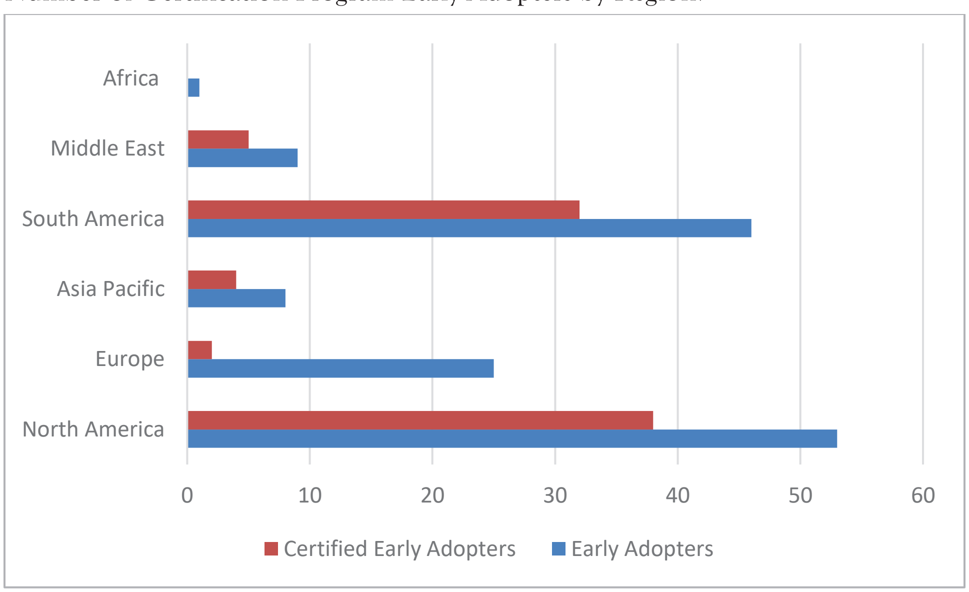
Appendix C

Percentage of SMEs by country



Appendix D

Number of Certification Program Early Adopters by Region.



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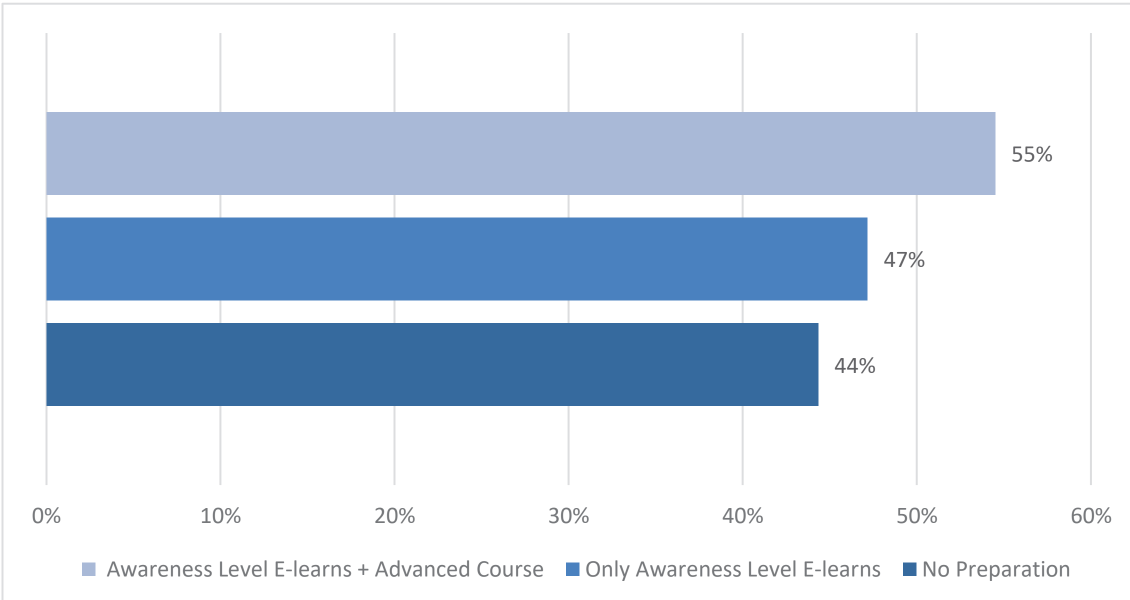
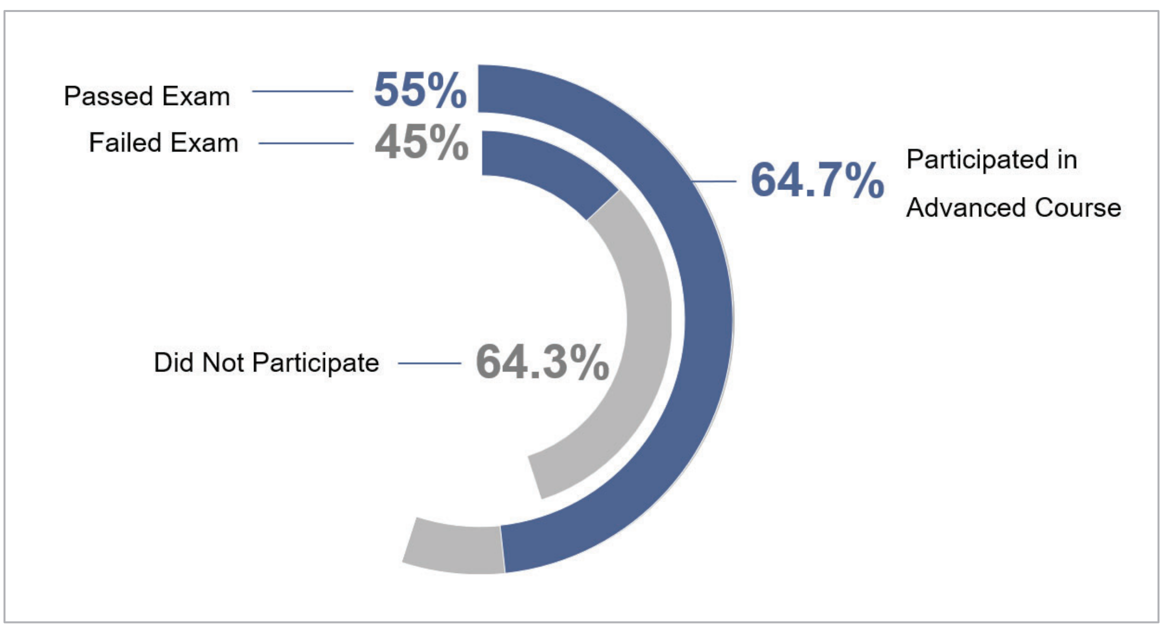
Appendix E

Average score of individuals by preparation.



Appendix F

Pass rate of individuals who participated in an advanced training course prior to taking the certification assessment.



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