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Software and systems engineering — Certification of software and systems engineering professionals —

Part 2: Guidance regarding description of knowledge, skills, and competencies contained in schemes

Ingénierie du logiciel et des systèmes — Certification des professionnels de l'ingénierie du logiciel et des systèmes —

Partie 2: Recommandations relatives à la description des connaissances, aptitudes et compétences contenues dans les programmes

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and systems engineering*.

A list of all parts in the ISO/IEC 24773 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

The ISO/IEC 24773 series replaces and expands upon ISO/IEC 24773:2008.

The ISO/IEC 24773 series consists of the following parts.

— ISO/IEC 24773-1 serves as the basis for the ISO/IEC 24773 series. It contains terminology, concepts, and requirements which are common to the remaining parts.

— This document contains guidance which can be used by certification bodies regarding the definition of knowledge, skills and competencies that are to be incorporated into a certification scheme for professionals in software and systems engineering.

— ISO/IEC 24773-3 provides specific requirements for certification schemes for professionals in systems engineering.

— ISO/IEC 24773-4 provides specific requirements for certification schemes for professionals in software engineering.

The ISO/IEC 24773 series is applicable across all organizations and for conducting assessments using a variety of methods, techniques and tools.

This document also contains additional discussion and guidance concerning the requirements for certification schemes defined in ISO/IEC 24773-1. It contains general guidance concerning the elements of a certification scheme, particularly as they apply within the domain of software and systems engineering. It contains guidance for the description of several key elements of certification schemes which are generated or referenced by the certification body:

— body of knowledge (BOK);

— skills;

— competency.

In addition to addressing technical skills, knowledge and competence, ISO/IEC 24773-1:2019, 6.3.1 requires that a conformant certification scheme address other aspects of professionalism, such as professional skills/attributes and a code of ethics. This document provides additional descriptions and guidance regarding these other aspects of professionalism to be addressed by a conformant scheme.

This document is useful to certification bodies offering schemes for the certification of professionals in the domain of systems or software engineering. It offers guidance for certification bodies when defining or designing the various elements of their respective certification schemes, as well as guidance for description of these scheme elements.

Annex A contains further explanation about the distinction between certification and professional licensure. Annex A also contains additional guidance to encourage harmonization between a certification scheme and the requirements of regulators.

By considering the guidance contained in this document, certification bodies can provide a clearer and more precise description of their certification schemes. This in turn benefits the other stakeholders (potential certificants, accreditation bodies, professional and technical groups, and employers), allowing them to more accurately assess the certification scheme and compare to other schemes. This document is also useful to (potential) applicants or candidates of certification schemes, in that they can obtain additional background information concerning the requirements for certification schemes claiming conformance to the ISO/IEC 24773 series. Understanding the requirements for a certification scheme (as expressed in ISO/IEC 24773-1, ISO/IEC 24773-3, and ISO/IEC 24773-4) along with the guidance contained in this document, helps the candidate to compare various schemes, and understand where/how such guidance is reflected in and incorporated into the various schemes. Similarly, employers; evaluators of professional personnel who are certificants; and evaluators of certification schemes in the domain of software and systems engineering can also use the contents of this document to better understand the requirements, as well as the differences between various schemes.

Software and systems engineering — Certification of software and systems engineering professionals —

Part 2:
Guidance regarding description of knowledge, skills, and competencies contained in schemes

1 Scope

This document contains guidance for certification that can be used by certification or qualification bodies regarding the description of knowledge, skill and competence within their particular schemes based on ISO/IEC 24773-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 17024, *Conformity assessment — General requirements for bodies operating certification of persons*

ISO/IEC 24773-1:2019, *Software and systems engineering — Certification of software and systems engineering professionals — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO/IEC 17024, ISO/IEC 24773-1, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
KA
knowledge area
sub-area or grouping of related topics within a body of knowledge (BOK)

Note 1 to entry: See 5.2 and 5.3.

4 Major elements of certification and qualification scheme

This clause introduces the major elements of a certification and qualification scheme as listed in ISO/IEC 24773-1.

Clauses 5 to 8 discuss the various elements in greater detail.

Conforming certification schemes have the following major elements at a minimum:

— body of knowledge (BOK);

— skills;

— competencies.

Figure 1 depicts these elements and the relationship between them within the context of a certification scheme.

The body of knowledge (BOK) associated with a certification scheme contains items of knowledge which are relevant to the engineer or professional in the domain being targeted by that certification scheme. Recommendations for describing the BOK for use in a certification scheme are explained in detail in Clause 5.

NOTE 1 Also see ISO/IEC 24773-1:2019, 5.3 for the explanation of knowledge, BOK and cognitive level.

Skills defined for a certification can represent various abilities of the certificant, such as the ability to apply specific knowledge in the performance of an action, or a single step within a sequence. Recommendations for describing skills are explained in detail in Clause 6. Since skills are defined based on a certain set of knowledge topics, Clause 6 also contains recommendations about relationship between knowledge and skills.

NOTE 2 Also see ISO/IEC 24773-1:2019, 5.4 for the explanation of skill and performance level.

Competencies represent the ability to successfully complete tasks that certified persons are expected to undertake. Each competency required by the certification scheme is associated with appropriate proficiency levels (see ISO/IEC 24773-1:2019, 6.5.3). A competency area may be defined and may include various related competencies. Recommendations for describing competencies for use in a certification scheme are explained in detail in Clause 7. Since competencies are defined based on a certain set of knowledge topics and skills, Clause 7 also contains recommendations about relationship among knowledge, skills and competencies.

NOTE 3 Also see ISO/IEC 24773-1:2019, 5.5 for the explanation of competence and proficiency level.

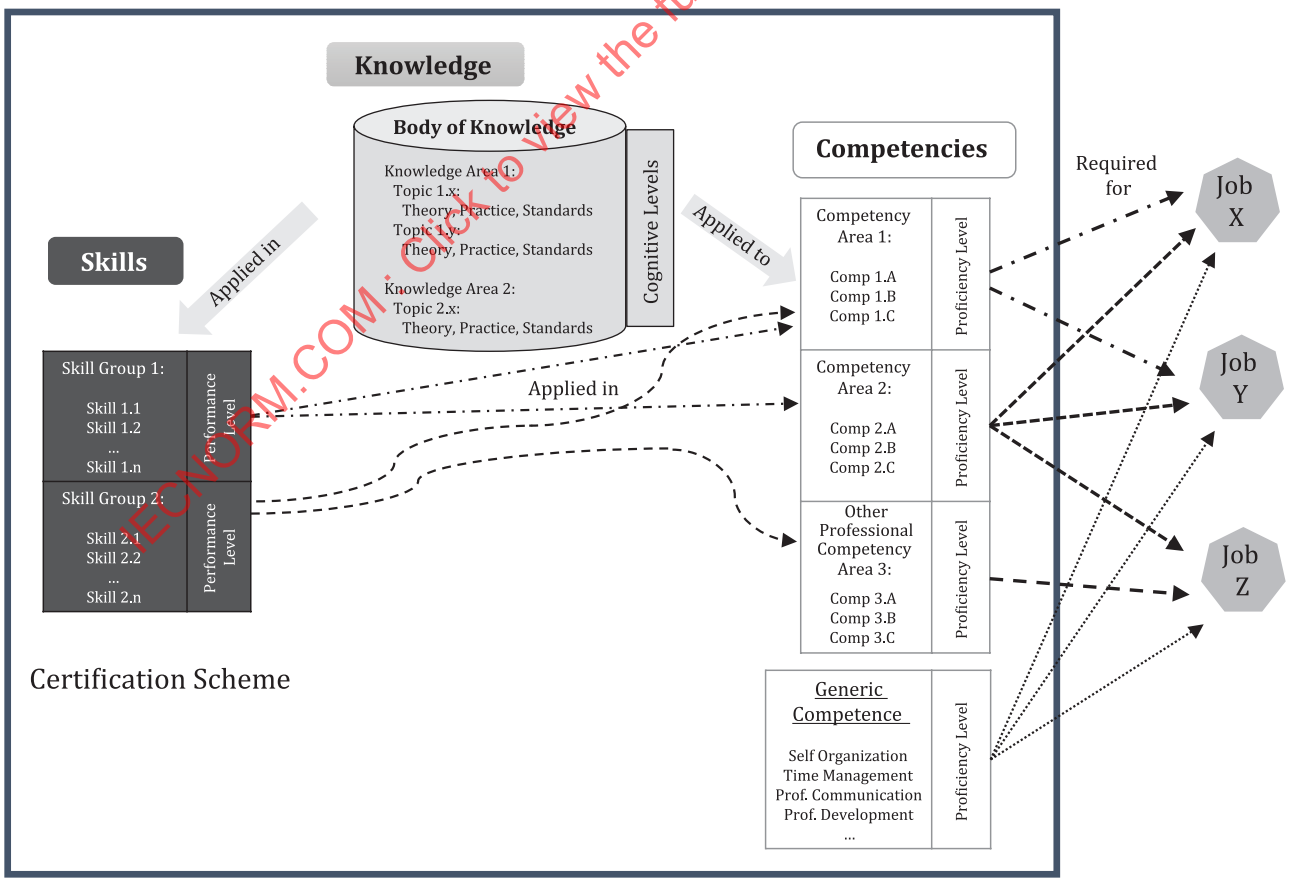

Figure 1 — Major elements of certification scheme and relationships among them

Other relevant elements of a professional certification scheme are not depicted in Figure 1:

— individual attributes (refer to 8.1);

— pre-requisite education or other pre-requisite qualifications;

— other KAs not in the reference BOK (refer to Clause 5).

Clauses 5 to 8 in this document provide additional guidance related to these elements.

The CASCO document "How to Develop Schemes for the certification of persons"[11] provides useful introductory information about and general guidance concerning certification schemes and certification bodies.

5 Recommendations — Body of knowledge (BOK)

5.1 General

The following recommendations apply to the BOK as used within a certification scheme for professionals in the domains of software and systems engineering.

Within ISO/IEC 24773-1 and ISO/IEC 17024, a BOK is a required element of a certification scheme.

The term "body of knowledge" is used within many contexts, both in industry, academia and professional bodies. The scope and meaning of a BOK should be clarified, especially since any particular BOK may be used for many purposes.

Accordingly, the certification body may choose to construct and define a BOK specifically for its own certification scheme. It may choose to adopt another (externally defined and controlled) BOK for use in its certification scheme. In a pragmatic approach, the certification body may construct a unique BOK by assembling reference material from existing sources.

5.2 Scope and depth of a BOK

The purpose and scope of any BOK should be clarified – whether that BOK is utilized as an element of a certification scheme; as a foundation for academic syllabus or curriculum; or as a basis for professional regulation.

A BOK, for the purpose of this document, provides the underlying knowledge contained within an appropriate set of topics grouped into KAs (illustrated in Figure 1). The enumeration of topics, in a sound structure or hierarchy, is essential.

A certification body may choose to assemble a BOK using several approaches (see subclauses in Clause 5). However, the BOK should always be managed and treated as a whole; and the certification body should ensure the integrity, accuracy and currency of the BOK as a whole.

The scope of the BOK should be consistent with the purpose and intended use of the BOK. In the case of a BOK associated with a profession or a professional discipline, the BOK should at least cover the essential knowledge of the discipline. That is, the scope of the BOK should include all relevant KAs. See additional suggestions in Clause 5 concerning coverage of "related disciplines" and "supporting disciplines".

The scope and depth of knowledge contained in the BOK should be consistent with and sufficient to support the various skills and competencies defined as other elements of the certification scheme. This completeness and sufficiency should be validated.

The depth of the material covered by the BOK should also be consistent with the purpose and intended use of the BOK. For the purpose of a professional discipline, if a KA is deemed essential and necessary for the understanding and practice of that discipline, then the material provided may be extensive in order to provide more detail. The knowledge provided in a given KA in the BOK should be provided in depth sufficient for professional practice.

A BOK may include or reference supporting KAs. Supporting KAs should be included in a BOK where such knowledge is directly required for professional practice, or where such knowledge is originating in another discipline (such as discrete mathematics, quality assurance or economics) and underlies the knowledge contained in the primary KAs. The information included in these supporting KAs may not necessarily be provided in depth and does not need to be repeated in the BOK if they are referenced to authoritative external sources.

Existing reports of BOK development projects such as "The Guide to the Software Engineering Body of Knowledge"[12] and "Towards a distinctive body of knowledge for Information Systems experts: coding ISD process knowledge in two IS journals"[13] may help design the purpose, scope, and depth of a BOK.

See 5.6 concerning "supporting or related disciplines".

5.3 Construction or assembly of BOK: content hierarchy and guides to BOK

A BOK may consist of many KAs. A KA may in turn consist of specific topics, and even sub-topics, arranged in a hierarchy.

The BOK should present information or knowledge for each defined KA. See further guidance in 5.4 concerning the quality of the knowledge sources referenced or used within a BOK.

However, the assembly or presentation of the knowledge content for a given KA or topic within that KA may be via reference to an external source.

Thus, the BOK itself may contain source knowledge material for some KAs, or it may provide references to external knowledge sources and not contain the referenced external source knowledge material directly. This approach has the advantages of:

— modularity – new references may be added or substituted easily when the content for a KA (or topics within) evolve;

— efficiency – external knowledge sources (provided they also meet criteria for source information quality) are already written and do not need to be re-written for the purposes of the BOK which incorporates them;

— external reviews and validation – in seeking to adhere to the highest standards of information quality and integrity, an external knowledge source may indeed have the benefit of thorough peer review and widespread recognition.

However, regardless of whether the BOK contains knowledge which is specifically written for a given topic, or whether a topic is covered by an appropriate external knowledge source, the integrity and accuracy of the BOK remains the responsibility of the BOK developer.

The BOK topic section should describe or summarize the objective knowledge inherent in the topic and contain citations which permit the reader to obtain more detailed information.

In the case where a BOK is broad and contains many distinct KAs, and where the depth of a BOK is significant, an overview or a summary should be included within each KA, before going into detail or citing references for sub topics. This summary provides a useful overview of the scope and depth of each major topic area. This is of great value for at least the following reasons:

— practitioners in the discipline (or users of that BOK) may not require all of the in-depth knowledge of every topic, but for the purposes of professional certification may need a certain amount of knowledge;

— the summary presents the nature and scope of the topic being treated (presumably by one or more external knowledge sources) and provides a rationale for inclusion of each of the external knowledge sources; this is helpful as a validation tool for readers and reviewers (and future maintainers) of the content for that KA.

A BOK document does not need to be one self-contained, encyclopaedic work. It may achieve depth and breadth by referring to other works, particularly when the cited works and their references are well organized and structured.

However, the BOK should have integrity in its resultant depth and breadth. A BOK should not simply cite a comprehensive text which in turn contains numerous sections and topics. The BOK should itself contain the structure of topics and subtopics, making specific references to specific topic areas in the comprehensive text. This allows for clean separation of knowledge topics and subtopics and also allows for focused review.

In the event that a BOK is constructed or assembled using many external references to authoritative knowledge sources, it may be considered a "Guide" to that BOK (e.g. Guide to the Software Engineering Body of Knowledge[2] and INCOSE SE Handbook[3]).

In this case, even though the referenced articles and knowledge content are not written directly by the developers of the BOK, the developers are still responsible for the integrity and quality of the BOK, including selection or coverage of topics, and the selection or referencing of appropriate source material. This means that even the content included via reference should be verified and reviewed. The content of the entire BOK should be reviewed and validated against the other elements of the certification scheme, including skills and competencies. In addition, when the BOK incorporates material via external references, special attention should be given to ongoing maintenance and updates to the external material. Refer to 5.11 for maintenance considerations.

The material within the BOK and even within each KA should be properly integrated. Each KA should contain an overview or a summary for each KA. An overview or a summary is especially important when integrating material from an external source or when blending original information with such externally referenced material.

Along with an overview of the content (from various sources) contained in a KA, the rationale for the selection(s) of the externally referenced content should be provided. See also guidance in 5.5 concerning "overlap between multiple knowledge sources".

Existing literature review and survey on BOKs in terms of their contents and structure such as "Open BOK on Software Engineering Educational Context: A Systematic Literature Review"[14] may help construct and structure contents of a BOK.

5.4 Professional orientation and style

The BOK (topics or KAs and the knowledge therein) should be selected and described for the purpose of professional use.

While some BOK may be created for other purposes such as academic purposes, a BOK used in a certification scheme for software and systems engineering professionals should be oriented towards professional knowledge.

In the case of knowledge relevant to a professional, not only "theory" but also the practical knowledge required by a practitioner should be considered. This can include:

— industry, technical and commercial standards;

— practices, methods and techniques;

— tools;

— current quality criteria and evaluation or verification methods;

— currently well-accepted empirical evidence, statistical knowledge related to the domain (various kinds and aspects).

The BOK should also contain information for each KA which reflects the detailed and precise knowledge needed by the professional. Information and external references should be suitable for use by professionals.

In the case of a BOK for a professional discipline or domain, the BOK should be reviewed by authorities responsible for professional practice in that discipline. See also guidance in 5.10 concerning review and validation of the BOK.

NOTE Validation of a BOK by a professional or regulatory body is not equivalent to validation or endorsement of a certification scheme which utilizes that BOK.

For this reason, certification bodies considering the construction of a new BOK vs the adoption of an existing BOK may determine that use of a recognized existing BOK may have an important advantage: the existing BOK may already have achieved recognition and validation from professional bodies or regulatory bodies.

5.5 Separation of topics and orthogonality

Topics for a BOK should be orthogonal – the intention is to have little or no overlap between topics or KAs.

Within the discussion and presentation of each topic and sub topic area, the description should remain focused and not attempt to covey knowledge contained in other topic areas or sections.

However, the inter-dependencies and relationships between topics should be recognized and treated within the BOK. For example, a treatment of "systems integration" as a topic may contain an explanation of the relationship to (along with a reference to) the related topics "interfaces and subsystem/component design", "configuration control", and "testing – integration".

5.6 Treatment of knowledge and references to other disciplines and other basic knowledge domains

The objective of a BOK for professionals in software engineering and systems engineering is to present knowledge within the discipline. As mentioned in 5.4, the BOK should contain or present the knowledge needed by a professional practicing with that discipline to be fit for use from the professional standpoint.

This presents a challenge to those who are responsible for the production of a BOK and to certification bodies, because the scope of both should be determined with respect to supporting and related disciplines.

Within a BOK written for the systems and software engineering discipline(s), it is impractical to include all the knowledge about the supporting disciplines. Further, the knowledge regarding these disciplines is not unique to or originating within the disciplines of systems and software engineering - they are authoritatively maintained elsewhere. Therefore, a BOK covering the disciplines of systems and software engineering should:

— enumerate the supporting disciplines;

— refer to existing authoritative BOKs or authoritative references for each supporting discipline;

— summarize within the software engineering or systems engineering BOK the relationship of the supporting disciplines to various topics and KAs in systems and software engineering;

— use a more detailed explanation (and more specific reference) to a knowledge source in one of the related disciplines where one is needed within a systems or software engineering topic or KA.

Presentation of knowledge within a supporting or related discipline domain may involve the inclusion of (or reference to) knowledge from other disciplines, mathematics and sciences.

Concepts, terms and facts from other disciplines should be introduced or referenced in order to convey their application in software or systems engineering KAs. The terminology and concepts from the other discipline should be accurately used or referenced within a systems or software engineering BOK, but not covered in depth.

5.7 Objectivity and verifiability

Source knowledge material and references should be written as true factual statements, written objectively and where possible backed up by supporting references, including origin and authorship of referenced source materials.

Subjective statements, opinions and unsupported or unverified content should be avoided.

5.8 Presentation of practical knowledge versus pure theory

Where a BOK is presenting information or knowledge relevant to professionals, it is possible that the material is not entirely proven. It may be the case that practical topics or knowledge are presented as current accepted practice, not as pure knowledge which has been proven beyond dispute. Such caveats should be annotated to these descriptions.

In such cases where practical knowledge is presented, various approaches or applications of theory may apply. Different schools of thought may exist and be accepted within the profession. Methods and techniques may be introduced in industry by professionals, but may not be proven or valid in all contexts. These should be presented as widely accepted or credible views, not as proven fact.

5.9 Bibliography and referenced source materials

While a BOK may reference external documents and source materials, the referencing should be precise (see 5.3). The complete bibliographic information should be contained within the BOK in order to make it easier for the reader and reviewer.

The referenced external source materials should also be available to the public.

5.10 Validation of BOK

The BOK for systems and software engineering disciplines should be authoritative and thus should be validated.

Where possible and especially where BOK topics make use of external reference materials (e.g. texts, scholarly papers, conference proceedings), such materials should be reviewed and accepted in academic and professional sense.

Reviews should occur during development. A review:

— should include experts and various stakeholders;

NOTE Stakeholders for a BOK can include academics, professional bodies, employers and industry groups as well as technical experts and individual professionals.

— may be done on a per KA basis, provided the BOK is well structured and the topics are reasonably orthogonal;

— of a KA should include the summary text for that KA as well as the detailed content;

— of a KA should include verification of all cited external references, and the rationale for inclusion into that KA;

— should also be held at the time of BOK / KA integration, in order to:

  — check for dependencies, relationships, overlaps or contradictions between KAs;

  — check for missing or duplicated content;

  — validate the BOK as a whole.

5.11 Maintenance of BOK

The BOK can contain (directly) a great deal of knowledge and factual information which is superseded or made obsolete. For example, frequently changing knowledge can be related to:

— tools;

— techniques;

— empirical evidence or statistical data related to the discipline and practice.

In order to be of value in the long term, the BOK should be modular in design and maintainable in the first place. In addition, planning and preparation for maintenance (correction or addition of content), updates and reviews should take place prior to the publication of the BOK. This strategy helps to keep the BOK up to date on an ongoing basis and is preferable to an ad-hoc or irregular approach to updates.

Maintenance should include provision for feedback and corrections from BOK stakeholders and BOK users after publication. Following the strategy of planning in advance for maintenance, the published BOK itself should contain a declaration of BOK maintenance policies, and information which provides instructions for users regarding the feedback mechanism.

The certification body is responsible for maintaining all elements of a certification scheme. See ISO/IEC 17024:2012, 8.5 for the relevant requirement.

Consequently, the updates and maintenance of the BOK should be done under controlled steps to ensure that the changes to the BOK are consistent with changes to the other elements of the certification scheme (including scope). The certification body should evaluate the impact of any change to the BOK (including KAs referencing external sources or BOKs which may have changed) upon their operational certification scheme. The changes to BOK content should be reviewed and approved. Other elements of the certification scheme (examinations, job review, competency definitions and assessment methods) should be re validated against the updated BOK prior to implementing a change to the certification scheme as a whole.

The issues to consider with respect to BOK updates and changes include:

— review and approval of the new BOK version;

— planning, scheduling and promotion of the introduction of a new version;

— planning, scheduling and promotion of the retirement of an old BOK version;

— planning and support for any overlap in use of the old and new BOK versions.

6 Recommendations — Description of skills

6.1 Skills are related both to knowledge and competency

When considering and defining skills in the domain of systems engineering and software engineering, the relationship of each skill to both knowledge and to competency should be examined. Figure 1 depicts this relationship.

Skills can be related to knowledge in the sense that a skill can represent the application of knowledge.

Skills can also be related to competency, which is the ability to apply knowledge and skills to achieve intended results.

Thus, if a certification body is considering skills definition, it can be helpful to use as a starting point:

— a BOK, if it already exists; for each KA or topic in the BOK, one may consider: “how is this knowledge applied?”;

— a set of tasks, or work products as a starting point; for each task or work product, one may consider: “what skills are involved or required in performing this task or producing this work product?”.

The required skills and their performance levels should be enough to fulfil the competencies required by a scheme. The underlying BOK should cover the knowledge required to execute the skills at the required performance levels.

“Generic competencies" and "Other professional competencies" are described in 7.6 and 7.7. The certification body may define these specific abilities in the Scheme. The certification body may choose to define these abilities as skills, following the guidance in this clause.

6.2 Skills are acquired and developed

Some general (abstract cognitive) skill categories include:

— reasoning;

— analytical skills;

— problem solving;

— innovation.

However, a certification body should identify in the certification scheme those practical skills (in areas such as systems analysis, software construction, testing) in the professional domain which are more closely related to specific KAs and competencies as appropriate for the certification scheme.

Skills are not intended only to reflect pure knowledge, but they can be viewed as the successful application of such knowledge.

For example, while a BOK may contain a KA related to software testing, and may include knowledge of certain testing standards, testing techniques and testing tools, the practical skills associated with testing may include:

— ability to identify when a particular standard or test technique is needed;

— ability to write a test conforming to a standard;

— ability to successfully apply or use a tool to implement a test.

6.3 Skills differ from individual (personal) attributes

Personal attributes like honesty, work ethic, cooperative attitude may be identified as part of the certification scheme and form part of assessment of a candidate. However, while such personal attributes may be observable, they may be difficult to evaluate consistently and objectively. These personal attributes are also difficult to relate objectively to software engineering and systems engineering competencies. For additional discussion of individual personal attributes, refer to 8.1.

6.4 Skills have performance levels

Skills are defined but the performance of a particular skill varies from individual to individual. Performance levels are defined for a given skill and this relationship is depicted in Figure 1.

When defining and describing an individual skill, levels of performance for that skill should be considered. Since it is assumed that a skill can be acquired or developed,[5] it is expected that an individual may gain that skill incrementally. In other words, the description of a skill can take into account some ability at one performance level (say at a minimum performance level or nominal performance level), while the description then also addresses the highest ability, which corresponds to the highest performance level defined for that skill.

6.5 Groups of skills and highly specific skills

Skills can be defined in groups or hierarchies, so that more specific skills can be addressed as part of a group of skills. This flexibility allows the certification body to add detailed skills of interest to the certification scheme. However, a certification scheme should contain not only very detailed and specific skills, but also broad skills and competencies, since the nature of software engineering and systems engineering domains is broad.

Existing skill and competency frameworks in software and systems engineering (such as SWECOM[1] and INCOSE Competency Framework[15]) and general ICT (such as e-CF[16], SFIA Framework[17], and iCD[18]) may help identify specific skills and competencies.

NOTE ISO/IEC 24773-3[19] contains requirements for skills in certification schemes for systems engineering professionals. ISO/IEC 24773-4[20] contains requirements for skills in certification schemes for software engineering professionals.

6.6 Maintenance of skills definitions and performance levels

The certification body is responsible for maintaining all elements of a certification scheme. See ISO/IEC 17024:2012, 8.5 for the relevant requirement.

The certification body should plan for regular reviews, maintenance and re-validation of all elements of the certification scheme, including the skills definitions and performance levels. The detailed skills definitions and associated performance level criteria defined and used in a certification scheme can depend greatly upon technical knowledge, tools and technology which may be superseded or made obsolete.

As with the other elements of the certification scheme, the skills definitions and should be modular in design and maintainable in the first place. In addition, planning and preparation for maintenance (correction or addition of content), reviews and updates of skills and performance levels should take place regularly.

Maintenance should include provision for feedback and corrections from experts and stakeholders.

The changes to skills definitions, performance levels should be reviewed and approved. Other elements of the certification scheme (examinations, job review, competency definitions and assessment methods) should be re validated against the updated skills definition prior to implementing a change to the certification scheme as a whole.

The issues to consider with respect to skills definition updates and changes include:

— review, validation and approval of the updates to skills definitions;

— review of any required changes to BOK KAs or competencies;

— validation of updated skills definitions with respect to competency definitions and assessment techniques;

— planning, scheduling and promotion of the introduction of the updated skills with a new release of the certification scheme;

— planning, scheduling and promotion of the retirement of any older version of skills definition (older version of certification scheme);

— planning and support for any overlap in use of the old and updated skills definitions (new certification scheme release).

7 Recommendations — Description of competencies

7.1 General

Competencies are related to both knowledge and skills. This relationship is depicted in Figure 1.

A skill can represent the performance of a simple action, the production of a single work product, or completion of a single step within a complex sequence. In contrast a competency can represent the completion of a complex activity, or the achievement of a larger goal (with broader scope than a single action or single step requiring the application of a skill).

Competencies can incorporate the application of multiple skills and knowledge, because these are all needed in order to complete the more complex activities and achieve larger more complex outcomes/outputs.

The certification body should take care to verify that all competencies defined are consistent with, and sufficiently supported by the skills and KAs defined in the certification scheme.

The required competencies and their proficiency levels should be enough to fulfil the required tasks.

As defined in ISO/IEC 24773-1, competencies are closely related to major functions activities and tasks performed by the professional.

Competency involves the successful completion of a set of activities or steps, where the output or result is as expected at the professional level.

Merely performing a series of steps or activities, and completing them, does not imply competence. A person who is non-competent may perform activities or steps and may apply certain skills and knowledge, but may not achieve the successful outcome defined for that competency.

In order to perform and complete an activity and successfully produce a result or outcome, skills and knowledge are applied. Judgement may need to be applied to complete the activity successfully and with the level of quality expected of a professional.

In some simple cases a competency may be described clearly by relating it to a very specific skill. For example, “creating a class diagram” is a smaller scale competency which may involve skills quite specific to UML: conventions and a diagramming tool.

In other cases, a competency may be defined which require various (broader higher level) skills and knowledge from several knowledge/topic areas. For example, “planning software assurance activities” may be a competency which involves knowledge of security, software design, software construction, as well as verification and validation. It may include knowledge of relevant criteria and standards, and involve the judgement of the professional regarding the project specific context (scope of the system, the environment, risks and domain specific criteria).

A given competency can be related to, or required in, a certain job. A given competency can be required in more than one job. However, the names and definition of jobs and the competencies required for a given job title are not defined in the ISO/IEC 24773 series and are not required elements of a conformant scheme. The certification body should define competencies clearly without referring to specific jobs or job titles in the description.

7.2 General objectives in describing competencies

Since competencies are more closely related to specific tasks and specific work products, it can be helpful to approach the competencies from the viewpoint of “what should the certificant be able to accomplish” – at a professional level.

A certification scheme is defined with respect to a certain scope, for a particular set of certificants working as software engineering or systems engineering professionals within a certain domain – the description of the certification scheme itself should contain a declaration regarding the nature of the “task” or focus of the certification scheme (see ISO/IEC 24773-1:2019, 6.2.1 and 6.2.2). Then the set of competencies defined by the certification scheme should be consistent with the nature of the activities to which the certification scheme is focused.

Competencies may be grouped into competency areas. Competencies should be defined which apply to professionals across the professions of systems engineering and software engineering, and not be tied specifically to a specific concrete job title or job description (see 7.3). Professionals in the fields of systems engineering and software may possess a set of competencies, regardless of their current job title or employment. For this reason, a certification scheme should define and assess a broad spectrum of competencies.

The scope declared for a given certification scheme may not cover all the systems engineering competencies described in ISO/IEC 24773-3, or the software engineering competencies described in ISO/IEC 24773-4.

However, it is a general objective for a certification scheme that all competencies within the scope of that scheme be declared and defined.

A competency shall be associated with appropriate proficiency levels (see ISO/IEC 24773-1:2019, 6.5.3) and see also 7.8 and 7.9). This also means that a given competency can be defined which allows for various outputs or outcomes at various proficiency levels.

7.3 Separation of competencies from titles or roles within organizations

Competency definitions may be related to job titles/roles. Within the context of a competency definition the system or software engineering professional who meets the criteria (proficiency level) defined for that competency should:

— perform certain tasks;

— produce certain deliverables;

— make decisions or evaluations;

— achieve results.

However, job descriptions within industry may also associate these tasks, deliverables and decisions with a particular role or job title. A role or job title may be associated with certain specific deliverables, technologies, or even specific work products. However not all job titles are standardized, and individual employers may vary the particular job description over time. For this reason, it is appropriate to define competencies for software engineering and systems engineering professionals in a manner which is not tightly bound to an industry job title or an employer specific job description.

Many job descriptions in industry are brief and may focus on listing specific tools or technologies required for the job, and not the broader aspects of a software or systems engineering competency.

Certification bodies may define skills in their schemes in order to address the use and application of such specific tools or technologies. A skill can be defined to cover the ability to apply a specific tool or technique; and the appropriate specific output from the application of that tool or technique.

However, the certification body may define competencies in order to address the broader tasks or activities, which may involve the application of many skills, and which may involve judgement in order to satisfy the outcomes associated with that competency.

A role or job title may also be associated with various management functions, and with decision-making authority within an organization. At higher levels of competency, engineering professionals are expected to perform functions beyond the simple application of a skill. The higher-level competencies for software and systems engineering professionals may include making large scale strategic engineering decisions; reviewing and improving quality; research and development; and mentoring of other professionals; defining standards; and evaluating the work of other engineering professionals.

However, in some engineering organizations, managers are appointed to perform some or all of these functions. They may be given job titles and authority, which can imply a high level of engineering competence, even if they do not actually possess the appropriate engineering competencies. For this reason, the job title of a manager or employee should not be used as an indicator of engineering competence, and the certification body should define competencies without direct reference to job titles.

7.4 Lower-level competencies and work products

As mentioned in 7.1, skills can be defined by the certification body and associated with the production of smaller individual work products. Work products in software and systems engineering vary in scale and complexity. For example, the term work product can be used to refer to a simple configuration status report, or it can be used to refer to a completed sub-system.

Competencies are suitable and appropriate when related specifically to larger broader outcomes and results (such as the implementation of an engineering lifecycle process, or the successful completion of a sub-system).

The certification body defines specific skills and competencies for the certification scheme, and so may choose to associate a skill or a competency with a specific work product.

In order to be effective, a competency definition that refers to a specific engineering work product should use an industry standard definition of the work product, and any work product attributes.

7.5 Use of external competency definitions

The certification body is faced with the responsibility of defining competencies of software engineering or systems engineering professionals covered within the scope of its certification scheme. However, if external competency definitions already exist the certification body may reference them.

All competency descriptions should be associated with proficiency levels and evaluation methods, so the certification body should address these if referring to externally written competency descriptions.

7.6 Generic competencies

A professional requires ability beyond the technical skills which are most frequently cited.

Generic competencies are generally non-technical in nature and can be acquired, practiced and improved by the individual professional. The competence may be essential in certain roles.

ISO/IEC 24773-1:2019, 6.5.6 contains the requirement(s) for generic competencies at a minimum.

All professionals should possess generic competence, in order to work effectively with others in a professional or business environment. The certification body should include in the certification scheme some additional generic competence beyond those listed as requirements in ISO/IEC 24773-1.

A certification scheme can address relevant generic competence needed by the targeted professionals to work with colleagues, managers, clients, and peers in a business and professional engineering environment.

Generic competence can include:

— communications skills, including writing and presentations;

— negotiations and business/professional relationship management;

— team leadership, cultural sensitivity;

— time management;

— awareness of professional regulations, obligations;[4],[6],[7],[9],[10]

— awareness of professional ethics;[4],[6],[7],[9]

— sustainability and environmental impact awareness, and incorporation of these considerations into engineering practices;[4],[7],[9]

— awareness of equity, and other social development principles.[4],[7],[9]

These competences are not unique to systems engineering and software engineering professionals, but they are common to all professionals and therefore should be part of any certification scheme which targets professionals and therefore should be part of any certification scheme which targets professionals. For this reason, not all generic competences are specified or listed in detail as requirements of ISO/IEC 24773-1.

See also 8.1.

The certification body may choose to treat generic competencies as "skills" rather than "competencies".

7.7 Other professional competencies

ISO/IEC 24773-1 contains general requirements related to the inclusion of competencies in the certification scheme. ISO/IEC 24773-3 and ISO/IEC 24773-4 contain specific technical competencies related to systems and software engineering respectively.

Other professional competencies, similar to technical competencies, require the application of knowledge, skill, experience, and judgement based on other professional disciplines outside of software and systems engineering. Other professional competencies are related to the practice of engineering, not individual skills.

Certification bodies can define and incorporate into the certification scheme other professional competencies beyond those required by ISO/IEC 24773-1.

Other professional competencies can be included in the certification scheme to cover non-engineering competencies (in other disciplines) such as contracts, economics and finance, or marketing, if these competencies are required for the activities of the targeted professionals in software or systems engineering.

Other professional competencies can also be defined with an emphasis on the ongoing practice and application of certain skills, knowledge and judgement in making better decisions and obtaining outcomes which benefit the profession, stakeholders, the environment and society as a whole.

Examples of other professional competencies include:

— competencies in other professional (non-engineering) disciplines such as contract law, economics and finance;

— responsibility for planning, executing, managing one's own CPD, learning and self-development;

— mentoring, development of colleagues and other professionals;

— development and advancement of the profession.

The UK Standard for Professional Engineering Competence and Commitment[8] contains a useful general description of various "areas of professional competence". These include technical competencies, professional behaviour, responsibility and commitment.

The certification body may choose to treat other professional competencies as "skills" rather than "competencies".

7.8 Proficiency Levels

The certification scheme shall declare and describe the proficiency level definitions. See ISO/IEC 24773-1:2019, 5.5 and 6.5.3 for the relevant requirement.

In addition to general descriptions of proficiency levels, the certification scheme also describes, for each specific competency, the proficiency level(s) which apply to that competency, and also the specific meaning and assessment criteria (at each proficiency level) for that competency.

For the same reason as explained in 7.3, proficiency levels should also be defined separately from titles and roles within organizations.

The certification scheme may use an externally defined competency model and may also use the proficiency level definitions in an externally defined model.

NOTE One example of an externally defined competency model which contains proficiency level definitions is SWECOM.[1] In the SWECOM model, the proficiency levels are referred to as "competency levels" (named Technician, Entry Level Practitioner, Practitioner, Technical Leader, and Senior Software Engineer). The general levels are described in SWECOM and associated with typical roles and jobs. See also discussion about proficiency levels and titles in 7.3.

Proficiency levels can be defined and utilized in several ways by a certification body within a scheme:

a) a standard structure or rating for proficiency levels applies to all individual competencies (e.g. there is a base definition for proficiency level “3” which is consistent across all individual competencies);

b) a standard for a summative proficiency level for the professional (i.e. at summative proficiency level “3”, the professional is defined to have attained at least a minimum appropriate proficiency level in each of the following individual competencies…).

Years of experience should be de-composed into meaningful activities, achievements, development of skills, demonstration of appropriate judgement. This implies that the certification scheme should not directly include “years of experience" in its competency definitions and proficiency level definitions.

This is particularly important for a certification scheme, which is meant to be valid across the vast population of professionals in software engineering and systems engineering. The nominal years of experience reported by a given professional may be significant, but there is no method of ensuring that a year of experience (for one given professional, with one given employer) is equivalent to a year of experience for another professional.

7.9 Maintenance of competency definitions and proficiency levels

All elements of the certification scheme should be maintained, reviewed and kept up to date with industry standards (see also 5.11 for maintenance of the BOK).

When a certification body incorporates and references externally defined competency definitions and assessment criteria, these should be reviewed, validated before incorporation. Since an externally defined competency definition may change, the certification body should constantly monitor changes, and evaluate the impact of any changes.

Any updates or potential changes to the competency definition(s) and associated proficiency levels should be evaluated and all other elements of the certification scheme should maintain consistency if an update is to be implemented.

The certification body is responsible for maintaining all elements of a certification scheme. See ISO/IEC 17024:2012, 8.5 for the relevant requirement.

The certification body should plan for regular reviews, maintenance and re-validation of all elements of the certification scheme, including the competency definitions and proficiency levels. The detailed competency definitions and associated proficiency level criteria defined and used in a certification scheme can depend greatly upon technical knowledge, a particular domain of practice, techniques and technology which may superseded or made obsolete.

As with the other elements of the certification scheme, the competency definitions and proficiency levels should be modular in design and maintainable. In addition, planning and preparation for maintenance (correction or addition of content), reviews and updates of competency definitions and proficiency levels should take place regularly.

Maintenance should include provision for feedback and corrections from experts and stakeholders.

The changes to competency definitions, proficiency levels should be reviewed and approved. Other elements of the certification scheme (BOK or KAs, job review, skills definitions and assessment methods) should be re-validated against the updated competency definition prior to implementing a change to the certification scheme as a whole.

The issues to consider with respect to competency definition updates and changes include:

— review, validation and approval of the updates to competency definitions;

— review of any required changes to BOK, KAs, or skills related to the changed competencies;

— validation of updated skills definitions with respect to competency definitions and assessment techniques;

— planning, scheduling and promotion of the introduction of the updated competency definitions with a new release of the certification scheme;

— planning, scheduling and promotion of the retirement of any older version of competency definition (older version of certification scheme);

— planning and support for any overlap in use of the old and updated competency definitions (new certification scheme release).

8 Other general recommendations

8.1 Individual attributes

In general, individual personal attributes are those individual characteristics and behaviours which are not specifically addressed or required at the level of professional qualities or behaviour.

The possession of such individual attributes enables the professional to work with others, and to participate in a work environment. In some cases, the lack of such individual attributes can prevent adequate performance of work and professional activities.

Examples of individual attributes include:

— honesty, integrity or trustworthiness;

— initiative;

— self-control and self-awareness;

— positive attitude, enthusiasm;

— basic social skills and courtesy;

— basic communications;

— team or group interaction;

— respect for others, cultural sensitivity;

— emotional intelligence.

Individual personal attributes are not directly addressed by the requirements in ISO/IEC 24773-1.

However, several “generic competencies” are mentioned in ISO/IEC 24773-1:2019, 6.5.3, and some of these can be described as individual attributes. Subclause 7.6 contains a discussion of the generic competencies or individual attributes which are required.

In constructing the certification scheme, a certification body may (but is not required to) specifically define individual attributes required of candidates. However, these should be considered and included as requirements in the certification scheme, if they play a valid role in the professional behaviour and performance of a certificant in the domains of software engineering and systems engineering. If the certification scheme defines individual attributes and includes them as requirements, these individual attributes should be expressed in a way that is observable and assessable.

NOTE Ethical and principled behaviour by an individual is not easily defined and is not included as a potential individual attribute in the above list. The inclusion of a code of ethics in the certification scheme is mandatory (see ISO/IEC 24773-1:2019, 6.6) and such a code can be simpler for the certification body to define than an individual attribute relating to ethical and principled behaviour. The inclusion of such a code within the certification scheme implies an understanding of that code — and an agreement to comply with that code — on the part of the certificant. However, such a code can cite principles, and is not necessarily written in the form of individual attributes to be assessed. More guidance concerning the code of ethics is provided in 8.3.