Competency Related Data Management (CRDM)

a proposed reference model

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1 Introduction

Purpose and scope

Purpose. The purpose of this proposed reference model is to specify data models and processes that enable the broadest, most economical exchange of useful competency-related data among and between communities of practice. The reference model must support different conceptual models of the problem space, as well as various existing best practices.

Scope. The scope of this proposed reference model includes common data models and the specification of some common processes. It specifies some starter set of scenarios that take advantage of the common data models and processes involving competencies. The scenarios meet specific business requirements identified in applications areas such as education, personal development and learning content development as well as hiring, performance improvement and training.

Many scenarios, many divergent beliefs

Based on experience and theory, there are many ways to look at the interrelated fields of competency, assessment, performance and learning.

This proposed reference model tries to (1) provide a framework that can be used to represent many of those visions and models and (2) capture or support existing data and best practices. The purpose of this model is not to eliminate the richness of ideas and implementations, but rather to act as a liaison between communities of practice aiming for the broadest, most economical exchange of useful information.

It must be clear that there are different scenarios corresponding to completely different business goals. For example, the needs of education, personal development and learning content development are clearly different of those of employability, recruitment, performance improvement and training. Nevertheless these different scenarios can still take advantage of common data models.

Scenarios and standards for data and modeling that are feeding into for this model include

- IEEE 1484.11.1-2004 Content Object to Learning Management System Communication Data Model
- HR-XML Competency 3.0 draft
- HR-XML Assessment 3.0 draft
- IMS Reusable Definition of Competency or Educational Objective (RDCEO)
- IEEE P1484.20 Reusable Competency Definition
- LETSI SCORM 2.0 (draft)
- European Qualification Framework (EQF)
- Various LMS implementations and descriptive documents
- Various documents, articles or books describing or referencing competency modeling and competency and performance management.
2 Competency Definitions

Some of the terms used in this document may have different nuances in different application domains and communities of practice, therefore, we will introduce some of the main terms used in this document. This is to be seen as the onset of a broader effort to reach consensus on “Common Semantics for Employability”, a target for which HR-XML and IMS recently agreed to setup a joint liaison group.

Competency means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. Therefore, the concepts (1) skills, (2) knowledge and (3) abilities are subcomponents of competency.

Examples of competency:
- Generic competency: Applying knowledge and understanding.
- Subject competency: Apply concepts taken from anthropology, economics, geography and technology to an interdisciplinary study of international development.

Knowledge means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study.

Skills mean the ability to apply knowledge and use know-how to complete tasks and solve problems.

Learning outcomes means statements of what a learner knows, understands and is able to do on completion of a learning process. In other words, it is a list of user competencies which include knowledge, skills and attitudes.

Qualified Competency: competencies can be qualified by using qualifiers such as level (of proficiency, importance, expertise), or being assigned a relevance, ageing, weight factor, or being mandatory/optional, etc ...

Competency Framework: a reusable set/repository of competencies and qualifiers used by multiple organizations, teams or groups, to compose different competency models

Competency Model: a specific selection of reusable competencies and qualifiers to be used in an specific setting

Competency Profile: as an instantiation of a competency model a Competency Profile (CP) is a set of (acquired/required) aggregated competencies with well defined co-relationships, that, together, acts as a truthful knowledge representation for a specific object type such as person, job, task, function, process, learning objective, learning outcome, etc

Competence = a competency (knowledge + skills + abilities) in a particular context (e.g, situation, domain)

Qualification means a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcome to given standards.

Nevertheless, in this reference model it is possible to collect and manipulate data relating to competency, regardless of what competency means.

This reference model identifies and defines a modular set of simple data structures. The simple data structures can be used
- as building blocks in more complex data structures.
- to capture various existing or new data.
• in different processes to implement various scenarios
• in different contexts (and sectors) to support different usage scenarios

3 Competency Standards Evolution

The IMS Reusable Definition of Competency or Educational Objective (RDCEO) specification was proposed to provide means to create common understandings of competencies that appear as part of a learning or career plan, as learning pre-requisites, or as learning outcomes. The specification can be used to exchange competency definitions between learning systems, human resource systems, learning content, competency or skills repositories, and other relevant systems.

The IMS RDCEO specification was then put to form the backbone for the IEEE LTSC Reusable Competency Definitions (RCD).

HR-XML consortium - dedicated to the development and promotion of a standard suited for XML specifications to enable e-business and automation of human resources-related data exchanges – developed an XML schema to enable exchange of information about competencies within variety of business contexts. The specification binds IEEE RCD definitions with information about the context and evidence related to the RCDs.

IEEE Competency Profile (CP) is a proposal for standardizing the describing of information about the relations between competencies of one person. The different types of relations between competency definitions (RCDs) in one IEEE CP are introduced later in this document.

![Figure 1: Evolution of competency standards](image-url)
ICOPER project (http://icoper.org) goal is enable the delivery of competency based learning experience. ICOPER will develop the IEEE Competency Profile (CP), in away that enable the representation of competencies (and relations between them) from both academic and workplace competencies. This is to enable the portability of leaner competencies into workplace competency applications.
4 Competency Framework (CF) --> Competency Model (CM) --> Competency Profile (CP)

In trying to make competencies useful for cross-organizational and/or cross-context settings we seek a number of communalities. An industry sector or a region may choose to setup a competency framework, holding all RCDs needed. Furthermore the framework defines the number of qualifiers to be used.

Finally the framework allows for one or more RCDs aggregation levels to be used. There are basically 3 different aggregation (complexity) levels for competency profiles (CPs); see figure 2:

- List (a flat collection of competency definitions)
- Tree or Hierarchy (a “competency taxonomy”)
- Correlated network (or ontology, typically represented by a complex graph in which arcs represent the semantic relationships between the nodes)

An single organization can now select RCD to compose one or more models, using specific RCDs, an aggregation level, and by assigning the right qualifiers. Once the model is defined, specific competency profiles are defined as (partial) instantiations of a competency model. A CP always is attached to an artifact such as person, job, function, role, process, task, learning material, ... (PCP, JCP, FCP, ...)

Regardless of the aggregation structure of the competency profile, it is a collection of nodes, and each node may represent a different RCD. The same RCD may be represented by different nodes in different profiles. The competency profiles are only profile containers. They are not competency definitions themselves, but they represent a set of known relationships between (reusable) competency definitions. Given an RCD that is represented by a node in a profile, you can use the profile to find its relationships with other RCDs.

![Figure 2: big picture of competency metadata management](image)
5 Basic Building Blocks for Competency Management

RCD Reusable Competency Definition
GUID Global Unique Identifier (a URI)
RCD_GUID Reusable Competency Definition GUID
QCDRef Qualified Competency Definition Reference
CP Competency Profile (aggregation/profile of RCDs)
ER (single) Evidence Record
EDR Evidence Distillation Request
PCP Personal Competency Profile
CRER Competency Required Evidence Records
xCp Competency Profile for another ‘artefact’ such as process, task, function, job, role, ...

Scenarios of Building Competency Profiles

This section shows how the building blocks (RCDs) can be used and related to form more complex data structures, such as the Competency Profiles (CPs):

Basic Competency Profile— example 1

A basic competency profile (CP) can be represented as a taxonomy which is a hierarchy of atomic nodes (CPNODE). Each node in the hierarchy may include the identifier of a reusable competency definition (RCD). The nodes “roll up” from lower level competencies into higher level competencies. In a more elaborate competency profile, the nodes may include a qualified competency definition reference, which also includes a qualifier such as levels of proficiency, expertise, importance or relevance and confidence ratings, ageing etc...

Evidence Distillation— example 2

An evidence distillation request can be formulated to specify that there is a need to assess for a specific level of proficiency on (1) a particular competence described in a reusable competency definition (RCD) or (2) of the full competency profile as a knowledge representation of the subject or subject group.

The distillation process therefore can be as simple as a single assessment or as complex as ‘distilling’ any evidence source available into the resulting CP. The result of an evidence distillation process is specific to a
person or group and references an evidence distillation request and the collection and processing of all evidence available.

Descriptive data about the raw evidence presented can be assessed, predigested and stored as evidence records. The evidence distillation process results in a Personal Competency Profile, being an instantiation of the Competency Model. As such it provides statements as to what RCDs are present and whether the required proficiency levels of the single RCDs was obtained.

Evidence Records– example 3

An evidence distillation request leads to a Personal CP defined as a set of RCDs. Each RCD is referenced by a node in a particular competency model (CM). This node has children, which means that the competency is decomposable. A more specific assessment request can be generated for every one of the component competencies, by just following the structure of the Competency Model (taxonomy).

As each component competency is assessed, an evidence record for that component competency is generated. The evidence records for each of the component competencies can be “rolled” up by following the profile defined in the competency profile as the instantiation of the competency model. The summary evidence distillation record may be generated as the result of rolling up individual evidence assessment results.

5.1 Reusable Competency Definition (RCD)

A Reusable Competency Definition (RCD) describes the aspects of a competency that are common and generic to different people, situations, etc. That is to all the reuse of the same definition for different purposes in different contexts and by different people or applications.

To enable their findability and reuse, an RCD is described with a set of metadata elements:

- GUID: a globally unique ID, which allows RCDs to be published and referenced in many automated or relational processes. For example, the same RCD may be referenced in metadata for a learning object or for an assessment instrument, and in an assessment request in a recruitment workflow. RCDs are ‘forever’ and their RCDID should be ‘globally unique’, not in the least because other data depends on them. If a new edition of a RCD is published, it must use a different identifier.

  - Title: human readable title of the RCD.

- Description: free text describing the RCD

- Definition: the creator of the RCD can specify a model and provides statements specific to that model.

RCDs may have additional metadata because they may be valuable intellectual property that may make it worthwhile to include them in trade transactions. Metadata may also be used to specify the kind of competency (e.g. skill, knowledge, ability, ..), qualifiers related to the RCD etc... The data model shown here is both represented in the IMS RDCEO specification and the IEEE RCD.
5.2 Competency Profile (CP)

Competency Profiles have their own identifier because profiles may be reused and referenced. They have additional metadata beyond title and description because CPs are valuable intellectual property that may make it worthwhile to store at least some of them in repositories and maybe include them in trade transactions.

5.3 Reusable Competency Definition GUID (RCD_GUID)

The Global Unique Identifier is used to identify an RCD, in most cases it’s a URI.

It can use the “Catalog/Entry” approach, where an RCD identifier is built from 2 parts that can be concatenated into a single string. This is similar to the IMS and IEEE LTSC building globally unique namespace identifiers in W3C XML.

The catalog part is a globally unique identifier for a catalog or naming authority; for example it identifies Corporation X, the skills inventory at Corporation X, or the O*Net catalog. The IETF RFC 2396 for URI (Uniform Resource Name) defines a format for such identifiers. The identifier may correspond to an ICANN registered domain name (e.g. corporationx.com”).

The format of the entry part of the RCD_GUID is specified by the catalog owner or naming authority, who is also responsible to ensure that the entries are unique within the catalog or name space designated by the catalog part of the RC_GUID.

The syntax of the parts of the RC_GUID must be such that, if they are concatenated, the result will be a valid URI string according to RFC2396.

The RCD_GUID is not a standalone building block—it is always included in something else. Therefore a RCD_GUID has no identifier of its own. The RCD_GUID can referencing a so-called Subjectory. A Subjectory is human readable semantic infrastructure that provides a global unique identifier to each concept. If the RCDID is referenced and defined by a Subjectory, the Subjectory is the registered naming authority, and the Entry is the name.

5.4 Qualified Competency Definition Reference (QCDRef)

A Qualified RCD Reference (QCDRef) combines an RCD ID with one or more qualifiers. The qualifiers are applied when the RCD is used to evaluate a competency for a particular person or context.
• The most common qualifier is a proficiency level. For instance, the European Qualification Framework (EQF) specifies eight levels of proficiency.
• But there are many other levels: importance, expertise,
• Or other qualifiers dealing with relevance and confidence rating, ageing
• US Dept. of Labor’s O*NET specifies qualifiers

A qualified competency definition reference can be included in an assessment prescription or assessment request: “Please assess Jan Hoel for competency X at the level of beginner”.

A difficulty in standardizing qualifiers is that there may be many different scales or vocabularies. For proficiency level, this reference model proposes a simple percentage scale (-100%..0..100%, or -1..1) onto which different level vocabularies can be profiled. This scale also profiles to IEEE 1484.11. It is important to note that the QCDREF has no identifier of its own because it is not a standalone building block—it is always included in something else.

Competency proficiency level scale include optional negative values. This allows direct profiling to the IEEE 1484.11.1 data model and to ADL SCORM 2004. A negative proficiency level could be used to specify a “damaging” level of skill, where a skill has been badly learned in such a way that it can actually cause damage, which is worse than not having learned it at all. A pilot who regularly crashes airplanes might get a worse proficiency score (negative score) than a pilot who has no experience yet (score = 0).

5.5 Competency Profile Node (CPNODE)

Typically, a node in a competency profile represents a particular competency. It may also represent an element or facet of a competency. For example, a competency node may have children node that represent aspects such as motor, cognitive and affective aspects.

A node in a competency profile may reference an existing RCD, or not. For example, a node may exist in a competency taxonomy only for the purpose of grouping other competency nodes. In a taxonomy, the node with the title “English skills” might exist only as the parent of other nodes that reference existing reusable definitions for specific skills. If a GUID of an RCD, a proficiency level or other qualifiers are specified, this part of the node data profiles exactly to a Qualified Competency Definition Reference (QCDRef).

Different types of profiles “wrap” a CPNODE into a more complex object, depending on the aggregation structure of the profile. For example, a taxonomy (tree structure) adds possible parent and child relationships to any basic competency profile node.

The node has an identifier of its own because it may be referenced from other parts of the profile structure, or even from outside the profile structure, e.g. there may be a reference to “node x in profile y”.

Competency Profile Nodes have additional attributes that are specific to the hierarchical aggregation structure of the taxonomy. Taxonomy nodes (aka taxon) have a parent node and may have child nodes. Only one node in the taxonomy has no parent; that is the root node. The parent, children and sibling
attributes may be implicit rather than explicit. For example, if the taxon is encoded as an XML document, the parent, children and siblings relationships may be implicitly represented by a hierarchy structure in XML.

- If a taxon has siblings, it may have a weight relative to its siblings. For example, in a particular competency model, writing skills may be more important than speaking skills.

- If a taxon has children, it may have associated rollup rules that govern how the child competencies "add up". For example, either A or (B and C) is required.

PS: The IMS Simple Sequencing specification and SCORM 2004 specify weight and rollup rules that could be applied here. (Letsi Scorm 2.0??)

A competency ontology node is more complex than a competency taxonomy node, because any node in an ontology may be related to any other using semantic rich or poor relations, and/or have different constraints over ruling them.

5.6 Evidence Distillation Request (EDR)

An assessment request is a reusable data object that includes a Qualified Competency Definition Reference (QCDRef) and therefore, a reference to a RCD. In addition to a proficiency level, other qualifiers in the QCDRef may also specify different assessment dimensions.

![Evidence Distillation Request (EDR)]

If the referenced RCD is also represented in a competency profile (list, taxonomy or ontology), the assessment request may include a reference to that competency profile. In that case, the profile can be used to determine automatically which component competencies, if any, will need to be assessed and how proficiency on those competencies will contribute to the target competency.

The assessment request may also include a list of one or more acceptable forms of evidence (see figure 3), which in turn dictate what kind of assessment is acceptable.

The assessment request may be generic, or it may identify a target person or group. For example, it might specify that all new hires need to be assessed on awareness of best practices for personal security.
As shown in the figure above, the universities are responsible for generating different types of evidence records. These evidence records are then contextualized (by linking them to related context where they belong/apply). The reusable evidence records then are distilled — using appropriate algorithms — into an RCD, which is the basic building block for competency profiles. It is important to note that the distillation process is done automatically using smart algorithms and input from experts in the competency domain.

Evidence distillation request (EDR) application example

Rob wants to specify a standardized way to assess a particular competency for which an RCD exists. He knows that the RCD is also referenced by a node somewhere in an existing competency profile.

Rob creates an EDR that references the RCD through a qualified reference. He also specifies which competency profile should be used to identify other related or component competency definitions for the target RCD.

Paul is a recruiter who needs to assess a candidate on a specific competency. He can look up the EDR’s available in his company and can reuse or cannibalize an existing EDR. Paul specifies the person to assess, as well as a particular assessment instrument to use. Paul then passes this EDR to the entity that will administer the assessment.

5.7 Evidence Record (ER)

An evidence record captures a proof of competency for a particular person and a particular reusable competency definition (RCD). The proof of competency is typically summarized as a true / false value. It
may also be qualified by a score which represents a measure of satisfaction or proficiency level. Note that this type of record may also be used to represent a documented absence of competency.

The confidence rating is assigned by the entity that manages or receives the data for the competency evidence record. Typically, it is determined by policy and based on the type of data source and the data source itself. For example, if the data source is an applicant’s resume it will typically elicit less confidence than if the data source is a 360º assessment or formal assessment.

A digital signature may be associated with an ER to assert its integrity and authenticity. This may be required by an application policy if this record is transmitted or stored without the supporting data.

In the TAS³ project the identifier of the person is typically opaque, but can be passed to a resolution system to uniquely finger an individual. If the entity that is asking for resolution person identity is not authorized, the resolution simply fails and privacy and security are maintained.

5.8 Competency Required Evidence Records (CRER)

The Competency Required Evidence Records (CRER) captures the set of required evidence records for a particular reusable competency definition (RCD) of a person/function; in addition to satisfaction and confidence scores. This means that for each RCD, a list of evidence records required need to be identified. Each competency (RCD) can require (and be related) to one or more evidence records (ER).

The proof of competency is typically summarized as the most reliable true / false value available from the Evidence Records (ER). It may also be qualified by a score (satisfaction or proficiency level).

Note that this type of record may also be used to represent absence of required competency.

Evidence to support the competency is provided by one or more evidence records. A competency profile may be referenced, because evidence records might address component competencies, or this record itself might be for a component competency.
Not by accident, this data model profiles to the data model embodied in the HR-XML Competency 1.x specifications. It also allows profiling to the IEEE 1484.11.1 and SCORM 2004 information models for "objectives"

**Competency Record (CR) application scenario**

Debbie is being assessed for a competency defined by an RCD as part of an annual review. This is the first time she is being assessed on this particular competency. She does a self-assessment, her supervisor does an assessment, and HR conducts a 360° assessment that includes this competency. Each of these assessments results in an evidence record (ER) for this particular competency.

The self-assessment evidence comes in first. A competency record is created, referencing the evidence from self-evaluation, that shows that Debbie satisfies the requirements of the competency, with a score of 100%, but this is tempered by a low confidence rating since this is a self report.

Next the evidence from the 360° assessment comes in. It shows that Debbie has a proficiency of 70%. Per company policy, this evidence has a higher confidence rating than the self-report evidence, and thus the competency record is updated to show a score of 70%.

Next the evidence from the supervisor comes in. It states that Debbie is unqualified. However, by company policy the 360° assessment evidence has a higher confidence rating than evidence from an individual supervisor. The supervisor’s evidence is not sufficient to modify the competency record.

**Competency Record auditing scenario**

Ken is involved in an accident, which brings into question Ken’s mastery of a particular skill. Ken’s competency record shows that he satisfies the requirements for the skill, with a score of 90%. An auditor uses the competency record to locate the supporting evidence records, and finds two ERs in the HR database. One shows that Ken stated he mastered the skill on his employment application. The other shows that Ken was assessed for that skill in an online test. The ER record that resulted from that test includes a reference to an Assessment Result Record (ARR) record with all the details of the test. The Assessment Result Record is no longer online, but can be retrieved from the company archives for inspection.

**Competency Record use of a competency profile scenario**

Ken is involved in an accident, which brings into question Ken’s mastery of a particular skill. Ken’s competency record shows that he satisfies the requirements for the skill, with a score of 90%. The RCD for the skill is referenced by a node in a competency profile, which is identified in the competency record.

The competency profile is used as a guide to identify the component competencies for the skill in question. The RCD_GUIDs for those competencies are used to look up the corresponding competency records, to
determine whether Ken was deficient on any of those component competencies. This lookup fails for one of the component competencies. There is no competency record stating whether Ken is qualified on that component competency. Ken needs to be assessed on that component competency, because this may have been a contributor to the accident.

**FINAL NOTE:**

It is increasingly clear that a "task model" (taxonomy or ontology of the tasks) separate from a competency model (collection of RCDs and small, ad-hoc competency hierarchies) may be the way to go to make it all work, where:

- **task** = something that is done, or that needs to be done
- **competency** = what the person or team doing a task needs to master in order to be able to do the task

A reusable task definition has about the same "aggregation structure" as a competency definition (see Task in ASAT), in that it has:

- title
- description
- statements (action, condition, criteria)
- possible related tasks

Task definitions can be assembled in a "job description" that also provides context for each task, e.g. "removing a wheel" can be a task in a garage mechanic job description, but can also be a task in a convoy driver job description. By recognizing that there are a lot of those (e.g. thousands of occupational definitions) that may be very complex, it is possible to keep the competency/training side of things simpler and manageable by not having to represent all that complexity in the simpler competency models (simple trees) used for training.