Competency Semantics Information Modules and Architecture

Implementation, Exchange and Management of Competency Information in Learning, Education and Training IT Systems

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***Abstract*- The structure and organization of skill and competency information within Information Technology (IT) systems to support learning, education and training have not been widely researched in the fields of e-Learning and learning science. Although there are IT systems (e.g., Learning Management Systems (LMSs), Human Resource Information Systems (HRIS) that use and produce this type of information in the form of educational objectives, course content, learning resources metadata, and so on, very few systems are well integrated and capable of easily exchanging and managing competency information. Over several years, the Japanese government has developed several Japan national skills standards for lifelong learning, career development, and certification. They have had to address problems in terms of how various stakeholders can use, implement, and share the content of the information of skills specifications and standards using IT systems. Modules and architecture for skill and competency information content were needed in order to reuse and share this information and to optimize interoperability across various IT systems. Several reviews were conducted and modules and architecture were developed based on ontological engineering and practices. During this process, five types of expressions were discovered, and these were used as a basis to support further modularization. Based on the modules, a system-architecture to deal with the semantics of skill and competency information was developed.**

Keywords- Competency Modeling; Competency Management; Human Resources Management System; Semantics Technology; E-Learning; E-Portfolio

I. INTRODUCTION

A. Simple Competency Information

The concept of ability, which means that an individual can do something, can be expressed using various terms such as, “knowledge”, “skill”, “intelligent”, “competency” and so on. Concepts of ability are essential for the operation of human resources management (HRM) and development (HRD). Additionally, the use of information technology (IT) can support the efficient and effective transfer of competency information across a variety of IT systems to support a variety of activities (e.g., HRM) [1]. In this paper, all concepts relevant to what individuals can do will be referred to as “competency”, and we will not explore the theoretical debates as to the nature of “competency”. For the purposes of this paper, “competency” will be viewed as a construct that may include a variety of composite sub-competencies and interpreted depending on the evaluation criteria, method, and metrics that are chosen.

Even though concepts related to competency can be ambiguous and open to interpretation, competency information can exist in the form of statements as natural language expressions, or as other forms of data. For example, a company identifies “*A skill*” as an important assessment dimension (factor) or educational objective. Then the title of “*A skill*” as a label is created and has the potential to be exchanged in the real world. IT systems (e.g., HRM system, e-Learning system) must work with competency information and data. Preferably, the competency information is given a clear label and a robust definition to support its management and exchange. With a clear label and definition, the competency information can be more easily managed and exchanged amongst stakeholders, organizations, and the other IT systems and applications. These systems and applications usually can deal with only title labels (e.g., “*A skill*” or “*B competency*”: as shown in the Table I) or level information of a competency (e.g., “*basic*” or “*middle*”: as shown in the Table I).

TABLE I EXAMPLE OF COMPETENCY INFORMATION RECORDS IN E-LEARNING APPLICATION

id	Title	Course Grade	Learning Time	Result
aaa01	A skill	Basic	2:22:22	finished
123aa	B competency	Middle	1:23:45	open

B. Competency Information Properties

From the late 1990s, some industrial and academic associations have developed information technology standards and specifications for competency and learning objectives, on a global level to address the interoperability requirements and environmental complexities of organizations [2]. These specifications are used as guidelines of modular composition to assist with the construction and management of competency information. Some examples include work spearheaded by the following organizations IMS Global Learning Consortium Inc. (IMS GLC Inc.) [3], HR-XML consortium, IEEE-Learning Technology Standards Committee (LTSC) [4], and also ISO/IEC JTC1 SC36 (ISO-SC36).

Some of these standards and specifications address interoperability issues through the provision of ways to identify and exchange competency information, including the provision of consistent associated metadata such as identifier, name, creator, date/time, and so on. These information properties are useful for identification, and indispensable for communication amongst different information technology for learning, education and training (ITLET) systems (e.g., in HRM, LMS, and others). Approaches that incorporate the use of consistent metadata have had some limited success in bridging the flow of information across diverse systems.

Hirata & Brown revealed several problems for management and exchange of competency information [5]. One of the main problems is how to express and exchange the semantics of competency. Some stakeholders and organizations require access to the semantic layer of the information being exchanged due to potential ambiguities in understanding the nature of the competency information being exchanged. Access to more detailed competency semantics is especially important to stakeholders, such as teachers, learners, instructional designers, personnel staff, learning content developers, and so on.

To address the issue of providing a common language regarding competency information, ISO/IEC JTC1 SC36 has published the Conceptual Reference Model for Competency Information and Related Objects (ISO/IEC TS 24763) [6], and the Japanese Ministry of Economy, Trade and Industry (METI) and its institute (IPA) have developed an information model for modular composition of competency semantics information [7]. The semantics information model has characterized information properties relevant to competency semantics, such as explanation, action, outcome, originating organization/institute, assessment method, and relationship. A set of competency information is useful to refer to and to understand what a competency is, as it resides within and is shared amongst information systems and also to better support human understanding.

C. Need for a Module Guideline for Competency Information

Several standardized specifications using information properties have been provided for identification, definition and expression of competency semantics by the associations and projects mentioned above. However, it is hard for ordinary employees and employers to select the correct properties with mutual understanding, and to specify a value for each property, because existing competency dictionaries, skills inventory and skills standards were made along with their own underlying theoretical concepts, statistical approaches, or practical know-how. These may have been developed without consideration for interoperability. Additionally, they may have been written in natural language text. This means that the competency information may be ambiguous; and, the documentation or information structures may be difficult to translate into a more standardized format. For example, Spencer & Spencer developed a competency dictionary that was generally adaptable in the business domain, including several competencies relevant to communication, such as "teamwork competency", "impact and influence competency" and so on [8]. Each competency was defined by explanation and behavioural criteria in the document, but all expressions were subjective sentences.

II. PURPOSE

The purpose is to represent and support human understanding of competency within an IT system to support human learning and development. Efforts to fulfil this purpose require the clarification of the most essential feature(s) of the concept of ability through the construction of hypotheses. The hypotheses constructions should be expressed and recognized by representation [9], [10] in a standardized manner that supports human understanding and sharing. Some examples from everyday conversation are provided below. We might say

A: "*He shows good sales performance.*" – Demonstrated competency that is based on evidence.

B: "*I see he might have exemplary sales skill.*" – Potential competency to be targeted for further development.

In the latter case, this "sales skill" is based on only an idea. The skill is not reflected through demonstrated ability, but may be discovered through observation. The observation may or may not be based on a psychological test or indicated through theoretical background. In contrast to this less formal approach, the Information Technology Skills Standard (ITSS) is the Japanese national skills standard for IT industry professionals. The skills standard was developed based on theory and practical evidence, and verified through psychological aspects. However, whether a certain competency is defined with a formal procedure or not, it must be conceptualized as a formal construct if it is to be used within an IT system.

Parsons replaces a concept for "what human can do", and provides a title or a label for it. Then it is possible to build a conceptual structure for what or how an individual can do something in the real world. This is done in order to recognize, assess, and communicate with stakeholders. In this paper, naming types, construction patterns, and description approaches regarding human competency information in the workplace are discussed through several existing competency information examples. The three viewpoints in these examples provide aspects of competency semantics. Based on the aspects, information modularization, ways to deal with competency semantics information are explored and a design is recommended for managing and exchanging competency information when using IT systems.

For the purposes of this paper, the three viewpoints explored were from Japanese national skills standards [11], [12], Spencer's competency dictionary and 21st century skills [13]. Each skills standard has more than one hundred skills titles as well as definitions for each title. The two competency dictionaries have 20 and 30 competency titles and definitions.

III. SEMANTICS INFORMATION IN COMPETENCY TITLE

Through reviewing all the titles of the skills standards and the competency dictionaries, at least five key types of

title representations were discovered. The five types are named below along with their distinguishing characteristics. Although a computer cannot understand the meaning of a title, a human can understand the meaning of a title because terms that are used to express the title have meaning. Discriminating the features of a title as it is expressed in words, humans can derive the meaning of a title. Then even if there is just title information, its meaning can be perceived. From the viewpoint of an expression pattern in Japanese, there are at least five types of title expressing skill and competency (Table II), 1) action expression, 2) abstract issue expression, 3) job expression, 4) task execution expression, and 5) specific technology expression.

The first type, action expression, is a verbal expression, using just verbs such as, -ing expression, or verbified noun [14], [15]. Usually this type expresses the general meaning of an action verb, not the specific meaning. For example, "analyse competency; action Verb [analyse]", "planning skill; action Verb [plan]", and "communication skill; action Verb [communicate]".

The second type, abstract issue expression, is a combination of action verbal expression and its object word. The combination of words expresses an issue with general or abstract level. For example, "problem solving skill" is a combination of "solving" and "problem". "Solving" is a verbal expression that is the same as the first type, but in this case "problem" is an object of "solving". Then the combination expresses the concept at a very general level, not for a specific issue or situation.

TABLE II CONTENT ANALYSIS MAP FOR COMPETENCY TITLE NAME

Type	Explanation	Example
Action	Verbal expression, general action word	Analysis competency Communication skill
Abstract issue	Expressing general or abstract issue, combination of verbal expression and general or abstract object word	Problem solving skill Concept structuring competency
Job	Job title, job family title, or a title of subject matter	Sales ability Technology development capability Statistical skill
Task execution	Combination of verbal expression and its object word regarding job or task for concreteness	Customer presentation skill Integrated management skill Market needs analysis skill
Specific technology	Combination of a specific technological term or unique word, and its object word or verbal expression	Oracle DB skill Wireless communication application skill

The third type, job expression, uses words related to a job title, a job family title, or a subject matter title. This single action verbal expression is the same as the first type, or a combination of action verbal expression and its object word, which is the same as the second type. But this expression type also includes requirements of specific knowledge, technologies, or job in the words.

For example, "sales competency" or "technology development skill" are expressed with an action verb of "sale" or "develop" similar to the first type, but "sales" in this case comes from job concept, not only just action. Sales skill has a context based on a business setting or job performance. Although "analysis ability" is difficult to view as something that would be characterized as "particular" because it is a very general expression, in the case of sales skill, we can suppose typical activities in a sales job, such as apprising customers of product information, communication with customers, persuading customers and so on. Only the action verb of "develop" is at the general level, but when combined with "technology", this can lead us to imagine a job family of developer or engineer. A title of "statistical" reflects the word of statistics as a subject matter in academic or core skill of a researcher job.

The fourth type, task execution expression, is a combination of an action verbal expression and its object word. The second pattern and this pattern can be distinguished from the viewpoints of relatedness of job or task, and concreteness. There are differences when comparing "problem solving skill" with "presentation for customer (customer presentation) skill". The former is very general; the latter is targeted to a particular job or task, and because the object word of "customer" is included, this relates to a particular business context or setting. Another example is "Integration management skill". It is also the fourth type. Integration management means a part of project management process which project managers have to execute.

The fifth type, specific technology expression, is a combination of a specific technological term or unique word, and its object word or action verbal expression. This pattern involves usage, process, procedure or execution and includes words such as knowledge and technologies. For example, "Oracle database skill" is expressed using the terms of "Oracle" and "database skill". The former term is just a unique and specified technology; the latter term suggests the meaning of usage in business and a skill development target of information technology.

IV. COMPETENCY SEMANTICS AMONG STRUCTURAL RELATIONSHIPS

Within IT systems that hold competency information specific constructs must be used and these often consist of several information entities. Usually skills standards and competency dictionaries are developed in the form of a hierarchal structure, which is a form of competency organization. An intensive competency, such as the root of the hierarchy, has several competencies as its children. In the case of 21st century skills, the root competency title is 21st skills. Competencies on the second layer are "life and career skills", "learning and innovation skills" and so on. Then these second layers consist of several grandchild competencies at the lower level.

Hierarchical competency structures are sometimes defined by component sub-competencies or other competencies. In the case of Spencer's dictionary, all competencies are defined with relationships to other relevant competencies. These parent-children relations and other relations among competencies indicate the semantics of each

competency. These relationships provide much more context and meaning compared to a single title of competency.

To address the semantics of competency information, there are certain parent-child or other relationships in information technology systems. Children are elements or factors for a parent. In other words, children express the meaning of a parent, at the same time a parent also provides context for children. These hierarchal structures promote enriched information to support human understanding and enable functionalities within IT systems.

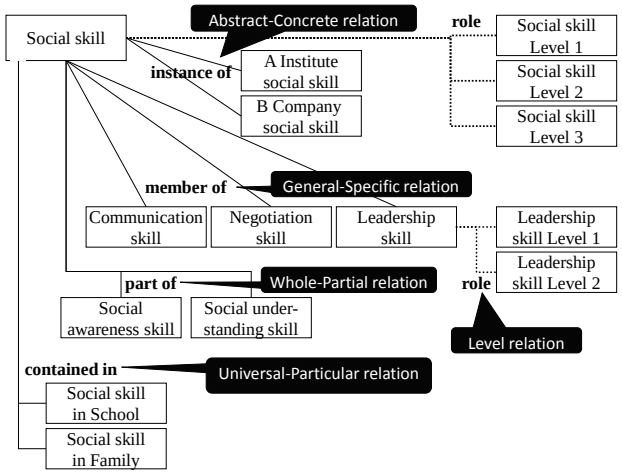

Figure 1 Relation Patterns of Competency Organization (Social Skill Case)

The features of hierarchal and other relationships of competency structures were reviewed from the perspective of ontological engineering (Figure 1), then several structural relation patterns were derived.

The first pattern, General-Specific relation, is the most typical in competency relations. A parent reflects a categorical concept or name of children. Its category bundles children based on the essential character of the competency identity and includes specific function. The pattern is shown as "member-of" relation in Figure 1. In the case of social skill, the essential characteristic is to approach and influence others. Communication skill, negotiation skill, and leadership skill also have this characteristic. In other words the social skill is generalizable to other skills.

The second pattern, Whole-Partial relation, is another typical pattern. Children are parts or elements of a parent. The pattern is shown as "part-of" relation in Figure 1. Its category bundles children based on relatedness. In the case of social skill, social awareness skill and social understanding skill are related to each other more than to the other skills.

The third pattern is Universal-Particular relation. In this case, the parent and children have the same meaning or the same characteristics, but there is no direct relationship among the children. The pattern is shown as the "contained-in" relation in Figure 1.

The fourth pattern, Abstract-Concrete relation, is instantiation. Children are objective entities of a parent, such as instance. Children come into same essential properties of parents such as attributes or factors. The pattern is shown as "instance-of" relation in Figure 1.

The fifth pattern, Level relation, is used to figure out the degree of competency. The parent has several degree or grade possibilities as level. The children of level do not reflect the meaning of a parent; however, the children of the level can express different states of execution. So children of level are not essential to the concept of a parent, these are recognized as the role concept to a parent. The pattern is shown as "role".

V. WAYS TO DESCRIBE COMPETENCY INFORMATION

Each competency is defined as a description. Many of these descriptions are written in natural language text. Some descriptions are defined using structural components, but often descriptions are provided in the form of a sentence. The meaning and context of competency are expressed in these sentences. The pattern of the sentence reflects the background principle or underlying viewpoint.

There are various ways of description and sentence forms. A description for a competency definition may be aggregated from several different content sources, with each having been formed from their own background principle or underlying viewpoint. In this research, all of the descriptions were divided into content level by linguistic case content analysis, and then all of the contents were categorized into linguistic cases [16].

For example, one of descriptions for "leadership skill" is

"to teach his/her subordinates, who have demonstrated correct performance, according to the task manuals",

In this case the description was divided into four components. The word *"teach"* is an example of a "verb", *"subordinates"* is an example of an "object", and *"have demonstrated correct performance" and "according to the task manuals" are* examples of "modifier" (see Table III).

TABLE III CONTENT ANALYSIS FOR COMPETENCY DESCRIPTIONS

	Content	Linguistic Case	Element of Meaning
1	teach	verb	essential state of action
2	subordinates	object	
3	according to the task manuals	modifier	resources
4	have demonstrated correct performance	modifier	purpose of action

While each content item can be categorised by linguistic case, sets of content have associated semantics that can be used to discern the nature of the content. An aggregation by verb, object and/or modifiers expresses semantics for competency description as information elements. These information elements form the skeleton of a description as a competency framework. For example, "*teach*" and "*subordinates*" are composed, and the set expresses the meaning of the essential state element of the competency execution. The expression of *"according to the task manuals"* is a resources element for competency execution, and *"have*

demonstrated correct performance" is a purpose element for competency execution.

Using this procedure, ways of competency information description and associated sentences were reviewed and patterns of competency meanings were extracted. Then eleven elements were derived for describing competency meanings as follows and as noted in Table IV.

1) Functional content: Explanation describing the state of competency execution. Usually it is expressed with a verb and a key object, and is focused on essential functioning. For example, "influencing stakeholders" is a typical behaviour of social skill.

2) Relevant knowledge: Lists and/or explanations of knowledge relevant to competency. For example, "counselling knowledge" is closely related to social skill. Sometimes the relation is captured in an educational knowledge title, sometimes the relation is an element of the competency, and sometimes the relation is critical to the competency.

3) Prerequisite: Description of prerequisite elements before skill and competency execution. For example, if he/she does not "give one's mind to customers (attention)", social skills will be non-functional or will not be executable.

4) Result: Description by result, after skill and competency executes. For example, "social skill" is executed and affected in actuality to the correct object, then "fulfilment of customer requirements" can be traced as a state element.

5) Purpose: Description by purpose of skill and competency execution. For example, "to forge a trusting relationship with others" is a purpose of "social skill" execution. Result element is sometimes confused with purpose element. The former is a final state expression of object; the latter is an orientation of execution.

6) Task: Description by related tasks. Job and task require competency execution to be attained. For example, it is important to execute "social skill" in the task of "requirement analysis".

7) Resources: Information resources or reference materials in execution of competency. Some skills should be executed in conformity to legislation or other types of rules and procedures. And instantiated skills in a specific industry or organization may need to be done according to specific manuals or standards.

8) Tool: Tool is equipment, software or other devices that a person uses in execution of a competency. For example, programming skill requires not only knowledge of computer and software, but also the ability to use computer and software as tools.

9) Condition: Description of the environmental condition or prerequisite condition, which is useful to assess competency execution. For example, "social skill" is described simply as a state of skill execution, "persuading others". It is useful to describe more detailed state of skill execution, "persuading others who have xenophobia".

TABLE IV ELEMENTS FOR COMPETENCY MEANING EXPRESSION

Element	Explanation	Example
Functional content	Described as a state, which is explained with verbal expression of competency execution	Influence to stakeholders
Relevant knowledge	List or a set of knowledge titles regarding competency	Using counseling knowledge
Prerequisite	Prerequisite elements before competency execution	After a person gives his mind to others (attention), then…
Result	Output or results after competency executes	Fulfillment of other's requirements
Purpose	Purpose of competency execution	In order to build relationships of trust with others
Task	Description by related tasks or typical task in which competency is used	Execute on requirement analysis
Resources	Information resources or reference material required in execution of competency	Using operation manuals and standards
Tool	Equipment, software or other devices that person uses in execution of competency	Through communication management system
Condition	Environmental condition or prerequisite condition, which is useful to assess competency execution	Persuading others "who have xenophobia"
Measurement metrics	Metrics that can measure, judge, and mark execution or retention of competency	More than 5 points on a 7 point scale for customer satisfaction
Measurement method	Method that can measure and judge execution or retention of competency	3 questionnaire items assessed using 360 evaluations

10) Measurement metrics: Competency is defined by metrics for its measurement, whether a person has or executes a certain one or not. For example, "more than 5 points out of 7 points in customer satisfaction", this example is one of metrics for social skill to be judged. This kind of description can be estimated to competency execution.

11) Measurement method: Skill and competency is defined also by method for its measurement whether a person has/executes a certain one or not. For example, "paper-based test", which is knowledge-based, could be one of the assessment methods. A "360 evaluation" could be used to assess attitude or perceived competency from the various contacts made by the individual.

VI. DISCUSSION FOR COMPETENCY SEMANTICS INFORMATION IMPLEMENTATION

A. Title Data Implementation

Considering prior standardization activities and Sections III and IV, there are three detailed levels for title data implementation. The simplest level includes only an instance of competency title data, such as "social skill". As it is only a title, there is little space to consider for information module. In Figure 2, only the title is replaced on the left side of centre.

The second level is to combine title data with identification information. Basically it has one data frame for a certain competency information as information module in order to set and design for an application system or database. The computer cannot understand the context of this competency information by title label alone. But if its identification information is to be used widely and effectively, the identification information implementation for title should use a standardized metadata specification (e.g., RDF), which is critical for interoperability in order to exchange and reuse this competency information.

Typical metadata might be expressed as RDF (Resource description framework) using Dublin Core Metadata Initiative (DCMI) terms, which is an application of XML that imposes needed structural constraints to provide unambiguous methods of expressing semantics. A set of metadata includes core data elements such as "id", "title", "creator", and so on [17], [18]. So competency title information can be annotated thus with a set of metadata for exchanging and managing data as a module. DCMI and/or W3C provide structured metadata that are recognized as de facto standards. These enable the exchange and management of the module with interoperable components that are internationally recognized. These annotated essential metadata should set a competency title and a set of information, and name "sharable competency core information (SCCI)" as a module. Instances of RDF metadata specification and implemented data sample of SCCI are replaced on the left side at the bottom of Figure 2.

The third level is to combine title data or an essential metadata module with contextual information, and named "competency situational information (CSI)" as a module. In this paper, the term of semantics may be defined by three aspects. One aspect is identification of the existence of data. The second aspect is contextual information for data. ISO/IEC TS 24763 can provide some assistance regarding this type of concept [6]. It shows various entities relevant to competency, such as "actor", "institute", "environment", "criteria" and so on. These entities can be used as classes for competency information and data.

Based on the discussion of structural relation for competency organization in Section IV, the relationships with other competencies also show situational information for competency data. It is also useful to understand the semantics from the viewpoint of the whole concept being described using the competency information. Two types of information may be considered useful regarding competency structure expression. The first type is umbrella information, what kind of competency structure is being used to describe a certain competency and how it was designed or developed. The second type is the place information, where and what kind of relations a certain competency are placed. So, elements of taxonomy, placement, and relation are useful in order to express semantics of competency. Information model for competency context and its implemented data set as of 2011 are shown in the upper right quadrant in Figure 2.

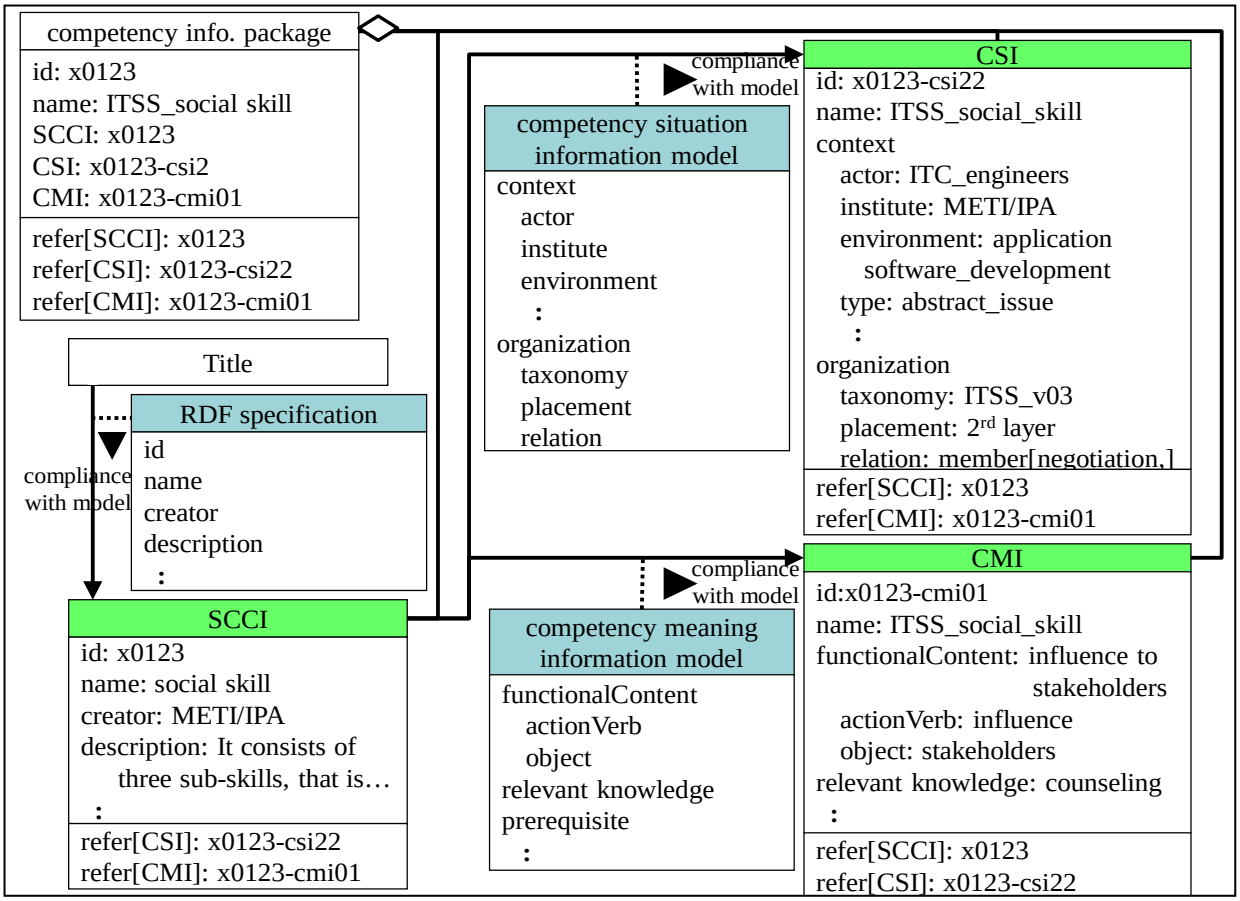

Figure 2 Competency modules and architecture

B. Description Information Implementation

A third aspect of semantics is the meaning of information contained in the constituent data. The fourth level is related to the third aspect of semantics focusing on content analysis for competency description. The fourth level combines a title data or an essential metadata module with meaning information, and is named "competency meaning expression information (CMI)" as a module.

There are many and various content information for a competency that may be found in a description. There are various ways the description may be found and described using natural language text. Some of these ways were discussed through content analysis in Section V. At least eleven elements were found as important for representation of competency meaning. These elements have to be implemented into systems or databases with a common information schema model, in order to support interoperability. There are no common tag titles for expressing competency semantics, and common schema for defining a competency, so these have been developed nationally in Japan in cooperation with the Japanese national committee. The properties of functional content, relevant knowledge, premise, and so on are useful in order to express the meaning of the competency. The information model for competency meaning and its implemented data set as CMI are shown on the right side at the bottom of Figure 2.

VII. CONCLUSION

The approaches used to represent competency using competency titles and descriptions were analysed and the features were extracted. Even for competency information that contained only a title, it was possible to infer contextual information from the title itself in some cases. Also, competency information that was organized in a hierarchal structure provided contextual information based on the relationships present between the components in the hierarchy. The descriptions provided for the competency titles had rich information that could be harvested and analysed to assist with understanding the meaning of the competency content. The sentences in the descriptions were researched using content analysis. Through this analysis, eleven different elements were found and characterized as supporting the representation of competency content. Although more research needs to be done, these initial analyses provide some suggestions where further work needs to be done to confirm the patterns that were found and to discover additional patterns within competency information across different IT systems.

In this last decade, several standards organizations have published specifications for competency information exchange and management, but most of these specifications only focus on data identification, and do not directly focus on context and content of competency representations.

Based on this research, patterns of information module and implementation examples to deal with competency information context and meaning were discussed. Through this work then all of the skills of the Japanese national Embedded Technology Skills Standards (ETSS) were designed and implemented into the system along with the above module and information architecture. Through these experiences, some advantages of the modules and architecture have been identified.

At first, each ETSS skill was honed and made more understandable by using natural language text and by using module representations with associated properties. Then users could customize ETSS for their own company needs with clear understanding and appropriate procedures.

Another benefit of this process was the ability to reach mutual understanding amongst different communities. In the case of "social skill", ETSS, ITSS and other competency dictionaries listed the term of social skill. But there were different meanings in each. They tried to find common meaning and to bridge the competency dictionaries that were being used by each company. Before using this module, previous efforts in this regard have always failed. When they used modules, they found differences; one defined it with performance criteria as measurement metrics and result in a practical situation, and the other one defined it with an indispensable knowledge and task.

Much work remains to be done, as application software needs to be developed to use these modules optimally. This is one of the research issues moving forward. And for the development of an application, the other issue is to clarify how it is to be used and combined in practice, for example, to explore how competency information is also used in resumes, learning histories, profiles, or job specifications. So this is another challenge that needs to be addressed to ensure that competency information can be shared and used with other types of information or systems.

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