Quality Management of Learning Content and Assessment: An Exploration of Application Methodologies Based on a Competency Semantics Information Model

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Abstract Competency information can be used to support quality management in e-Learning and assessment. This paper focuses on the exploration of two methodologies that were developed using a competency semantics information model in order to support quality management of learning content and assessment. Learning content including testing content and assessment events were analyzed in detail using the model. Both methodologies were based on a quantitative analysis approach as defined within the field of quality engineering. The two methodologies were used in a complementary manner and the gaps were identified between learning and test activities and between competency definition and assessments used. The resulting gap information from the implementation of these two methodologies can be used to support quality management.

Keywords: competency information, quality management, human assessment, learning activity

1. Introduction

There is a global trend evidenced in advances in learning technologies and renewed educational policies, to better support the exchanging of learning content and to expand the ability to support learning credit transfers among various organizations such as universities, companies, government ministries, etc. There are many examples of these activities, such as the development of open universities and organizations that design and share their learning content and associated metadata (e.g., Open CourseWare Consortium (OCW) and Global Learning Object Brokert Exchange (GLOBE)). In Europe, the Europass initiative provides opportunities to clarify and support the sharing of individuals’ skills and qualifications across national boundaries. It promotes workforce mobility through the transparency of skills and qualifications, competences, and common curriculum vitae (CV), among other things.

Some national and international institutes have developed common references, roles and information and communication technologies (ICT) systems to meet the growing global demand for learning flexibility and employment mobility. One approach to support common references is the development and use of competency lists or competency dictionaries for human development, learning, and training. These types of approaches can be used to help foster exchange and quality management activities related to online learning. Competency dictionaries can be used to reflect to policies of admission, diploma and curriculum. For example, they can be used to identify, implement, and evaluate the effectiveness of learning content. A critical success factor for these types of approaches is to ensure the involvement of governments, learning institutions, commercial organizations, professional associations, and others to reach agreements on the development and usage of common competency structure representations (e.g., dictionaries, national occupational classifications, frameworks, etc.). These agreements have the potential to benefit and to increase facilitation of learning content exchange, learning flexibility, and employment mobility.

From the late 1990s, some industrial and academic organizations began to develop information technology specifications and standards not only for online learning delivery systems, but also to represent knowledge, skills and competency domains on a global level in order to address the interoperability requirements and environmental complexities of organizations. Organizations such as the IMS Global Learning Consortium(1), the HR-XML Consortium(2), IEEE-LTSC(3), and the W3C
have provided leadership in the development and dissemination of technical specifications and standards to support learning, education, and training.

However, these specifications and standards sometimes address competency information only from the viewpoint of data exchange, so problems that were pointed out by Hirata and Brown(4) still remain. In brief, it has been challenging to wrestle with issues related to competency semantics, and also difficult to meet quality management needs. Consideration of competency semantics information within specifications and systems is an approach that can help to solve these identified problems.

2. Purpose

One of the most essential features of the concepts of ability and/or competency is how they are represented within a system through the construction of hypotheses. The hypotheses constructions are expressed and recognized by representations(5, 6) that are sometimes easy to recognize, but more often seem to be ambiguous and subjective. It can be problematic to share and know with certainty and confidence how these representations have been structured.

For example, in conversation, statements could be made regarding an individual’s performance,

A: “Mr. X showed good performance during this project according to the customer.”
B: “I see. Mr. X might have advanced computer skills.”

In this case, using the term “computer skills” is based on only B’s idea. Of course, A may also be making a subjective impression of Mr. X’s ability. However, A expresses the fact of performance as a result—customer satisfaction. The skill is not reflected through any psychological test, correct behavior observation, or theoretical foundation.

To move beyond subjective observation to a more structured approach, the Japanese government, through Japan Ministry of Economy, Trade and Industry (METI) and the Japan National Institute of Information Technology Promotion Agency (IPA), has developed the Skills Standard for IT Professionals (ITSS) as the national career, skills and training standard for IT industry professionals(7, 8). The ITSS was developed based on theoretical and practical evidence, and verified according to detailed psychological aspects. It has been influential not only in industry, but also within university education. It is used as a dictionary in the ICT industry. Statements can be formulated in a more structured way using the ITSS so that B in the above conversation might say:

B: “Mr. X might have advanced database system construction skills as defined within an IT specialist job career.”

It seems the statement of ability is more specific and easier to share through the use of common reference points. However, when a certain competency is defined, whether with a formal dictionary or not, it is helpful if competency is conceptualized, based on, and constructed with a common and shared understanding.

Often people create title data for competency information that is used to represent a concept for “what an individual can do”. Then they build a conceptual structure that represents what or how an individual can do something in the real world. This process helps people to recognize, to assess, and to communicate with stakeholders in practice.

In this paper, a competency semantics information model (a competency semantics model) is explained that is based on previous research. The competency semantics model was developed by the IPA in order to reduce misunderstanding and to promote mutual consensus. To further support these goals, the main purpose of this study is to develop a quality methodology for learning and testing content and assessment activities using the competency semantics model.

For this study, two complementary methodologies were developed and reviewed using real cases within existing IT systems. One of the methodologies focused on quality management of learning content. For this type of endeavor, traceability is the key for quality management. This means that information regarding testing results must be used, and the contents of learning and testing activities should be directly related. If not, the results information cannot be used for traceability. The other methodology focused on quality management of human assessment. The content of the competency definition and associated assessments were examined to determine the relationships and usefulness.

Both methodologies were developed using a quantitative analysis approach as defined within the field of quality engineering with the competency semantics model described below.
3. Competency Semantics Model

3.1 Existing specifications of competency information

The HR-XML Competencies specification, which is widely adopted within industry, was first published in 2003. The latest version was published in 2011\(^2\). The specification was developed with the intention of addressing issues related to competency semantics information. For example, it has elements such as competency evidence, competency weight, competency level, proficiency level, and competency taxonomies. But these elements can be used to define specific aspects of competency information, and there seem to be few specific elements or ways to specify semantics of content.

The JTC1 1/SC 36 Technical Committee of the ISO published a technical specification, ISO/IEC 24763, which dealt with a conceptual reference model for competency information and related objects in 2010\(^9\). It set nine information object classes for defining competency semantics, including for example action, role, outcome, assessment process, method and criteria, and environment.

Competency semantic approaches have been used in several European projects. For example, both the TenCompetence and eCOTOOL projects set classes of information elements into systems for competency semantics \(^{10, 11}\). Some examples of elements include task, activity, and job.

Although competency definitions can be described and implemented into systems as noted in previous research and standards focusing on the semantics level, there still remain limitations to dealing with the content meaning level.

3.2 Construction of a competency semantics model for the IT industry

The IPA developed a specification of competency semantics information for IT skills, called the skill meta model\(^{12, 13}\). The specification defined many competency elements as specific competency semantics with three layers in order to deal with content meaning. Some examples include, function content, processing (actionVerb), object, tool, prerequisite knowledge, situational knowledge, process, essential goal, taxonomy, relation, and placement. This focused on not only data semantics level, but also on the meaning level of description. The HR-MLs (Society of Human Resources Markup Language) developed the data specification for this model\(^{14}\).

This paper reflects on some of the outcomes and projects from the Japanese experience to arrange information elements for specifying competency meaning and sets them to include 13 elements; these are especially important to support a more objective approach regarding competency definitions and assessments. Most competencies are defined with descriptive text or a list of terms, and the underlying inherent logic may not be immediately apparent. These descriptions are written in text as natural language statements. Some descriptions are defined with structural components, but more often descriptions are subjectively explained by sentences. These sentences represent the meaning and context of competency or ability.

The pattern of the sentences used may reflect a fundamental background principle or viewpoint with respect to the competency. There are various patterns of description and sentences that are used. In this research, all descriptions in ITSS were divided into the smallest content size by linguistic case content analysis; then all contents were categorized into linguistic cases\(^{15}\). For example, one of descriptions for “leadership skill” in ITSS is:

“to instruct his/her subordinates using operation manuals and related standards”.

Then the descriptions, such as the one provided in the example above, were examined using content analysis to determine three different types of content. The first one is “instruct”, which is a “verb”. The second one is “subordinates”, which is an “object”. The third one is “using operation manuals and standards”, which is considered in this case to be a “modifier” (Table 1).

<table>
<thead>
<tr>
<th>content</th>
<th>linguistic case</th>
<th>property of meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 instruct</td>
<td>verb</td>
<td>essential function</td>
</tr>
<tr>
<td>2 subordinators</td>
<td>object</td>
<td></td>
</tr>
<tr>
<td>3 using operation manuals and standards</td>
<td>modifier</td>
<td>resources</td>
</tr>
</tbody>
</table>

Table 1. Contents Analysis for Competency Descriptions.
semantics that are context specific. An aggregation by verb, object and/or modifiers expresses the semantics of the competency description as information elements. These information elements form the skeleton of a description as a competency semantics framework. For example, “instruct” and “subordinates” are composed, and the set expresses the meaning of the essential function that can be measured to determine the nature of a competency demonstration. “Using operation manuals and standards” expresses the meaning of the resources property for competency demonstration.

Along with the analysis procedure described above, ways of description and sentence structures were reviewed to determine descriptive patterns of competency meanings. Then 13 elements were derived that were used to describe competency meaning. The 13 elements are described below and the competency model that was used as a basis to determine the elements is shown in Figure 1.

1. actionVerb: This is one of the essential units (eu) to explain competency demonstration. It expresses the action that needs to be executed or how input is to be transformed to output. It includes not only behavioral verbs, but also may include affective and cognitive verbs. This element can have sub-elements (e.g., children verbs).

2. object: This is one of the essential units (eu). Object is the target of an action or verb and is represented as a grammatical object or objective case. Action and verb can be qualified with object. The combination of verb and object is a typical pattern of expression of skill and competency.

3. relevantKnowledge (rk): This is knowledge that is needed before execution or during execution for attainment of correct competency execution or intended outcomes. It can be in the format of lists and/or explanation of knowledge relevant to the competency.

4. tool: This includes equipment, software or other devices that individuals use in demonstration of competency. These are represented as modifiers for actionVerbs. An action is executed using some instrument(s), materials, equipment, software or other devices that an individual uses in execution of a competency.

5. resources: This is the reference of a target competency or its performance. Documents of reference materials are used in execution of a competency. Some competencies should be executed in conformity to legislation, policies and procedures, or other rules. Instantiated competencies in specific industries or organizations need to be done in accordance with specific manuals or standards.

6. task: This is a part of job or duty which may be set not only in work, but also in academic activities. Competency is expected in and required for some tasks in general. Some skills may be named titles based on tasks identified in particular industry domains.

7. performanceProcess: This is a process or activity that consists of a competency and its performance. Executing the competency requires performance of some sub-activities or processes. Refinements are used to form child relationships. This element is used to elaborate child relationships by providing a breakdown of the process involved.

8. purpose: This is often referred to as the goal, aim, or orientation to perform or to acquire a competency. It means the reason why the competency is needed. This element gives context for the competency.

9. prerequisite: This is a description of prerequisite el-
elements required before skill and competency execution or acquisition.

(10) condition: This is a description of environmental condition or a prerequisite condition, which is useful to assess competency execution.

(11) outcome: This is a description of the outcome, after competency demonstration. It can include output, sequence and result(s) through action(s) required for competency execution.

(12) role: This is a perspective of the job role, position or specific functions that individuals have. A perspective might influence or direct orientation to competency execution.

(13) assessmentProcess: This is important to keep competency measureable. Assessment record information becomes evidence and is needed to support accountability. It may consist of assessment execution date, place, actor and records with methods and metrics.

4. Learning Content Quality

4.1 Framework of learning and testing symmetry analysis

For quality management in e-Learning, learning content is often reviewed and revised along with testing data. IRT (item response theory) or S-P analysis (student-problem score table analysis) are useful for test reviews especially from the quantitative perspective, but these approaches may not provide information regarding learning content directly. Learning activity time analysis using log data is effective to revise learning content, but it will not provide information regarding content itself.

Activity-based learning and testing symmetry analysis (LT symmetry analysis) which compares learning activities and testing activities was developed for learning content quality management using competency semantics information from a qualitative variation aspect. Table 2 gives a framework and example of LT symmetry analysis. Three learning content items and four test content items are listed in the table. Learning and testing content items are identified by each id on the left side of the table. Learning content items are analyzed as six aspects: activity level, instructional design (ID) method, actionVerb, objective domain, content type, and elements.

ID method is reflected by theoretical categories of instruction methods. actionVerb is expressed as learner activity corresponding to each learning or testing content. It is adapted by essential unit elements based on the competency semantics model. Domain shows type of learning objectives from the viewpoint of the educational objective theory, which are the three domains of Bloom's taxonomy. Basically the domain can be chosen from cognitive, affective, or behavioral corresponding to actionVerb.

Content type is an aspect of categories for contents, such as subject matter content type or rote/meaningful content types. There are mainly five subject matter content types: fact, concept, process, procedure, and principle. Fact is specific and unique data or instance. Concept is a class of items, words, or ideas that is known by a common name, includes multiple specific examples, and shares common features. A typical concept is definition. Process is a flow of events or activities that describe how things work rather than how to do things. Procedure is a series of step-by-step actions and decisions that result in the achievement of a task. There are two types of actions: linear and branched. Principle is guidelines, rules, and parameters that govern. It includes not only what should be done, but also what should not be done. Principle is the basic building block of causal models or theoretical models (theories).

Elements are made with descriptions of learning objectives for each learning and testing content. Learning objectives are merged by competency view; then its content is coded by elements along with the competency semantics model. Then content type and element are summarized in the middle of Table 2. The summary shows characteristics and a pattern of the content from a holistic view.

Four testing content items are listed in the lower part of Table 2 as examples. Each testing content is analyzed as six aspects the same as the learning content items.

4.2 Results of LT symmetry analysis

Based on analyses of learning and testing content with the framework, features of both were figured out from a qualitative aspect focusing on “activity”. The results are shown as total learning activities and total testing activities in Table 2. In the case of the learning content, there is one learning activity each for fact, concept, process, and principle, but there is no activity for proce-
dure. On the other hand, there is one testing activity for fact, concept and procedure, but two activities for process.

To compare learning and testing contents, LT symmetry analysis results are summarized as activity symmetry in the table. It is easy to indicate the difference between content activity and testing activity from a qualitative aspect. For example, both process and procedure are not matched. Process can be set by testing activity because there are two activities. Conversely, learners may not answer in procedure (procedure\[la (0), ta (1)\]), because there is no learning activity for procedure. Thus, failures can be found by the LT symmetry analysis. Furthermore, LT symmetry analysis can provide more detailed information by element part. Fact 1 (fc 01) may be learned repeatedly, while no learning activities for fact 2 (fc 02) and relevant knowledge 1 (rk 01) occur in the learning content.

### 5. Quality of Human Assessment

#### 5.1 Framework of assessment event analysis

One competency should not assess only one assessment method and event. Sternberg and Wagner\(^\text{18}\) pointed out that subjectivity in human assessment events such as in the assessment center method, critical incident method, 360 degree evaluation, and behavioral interview, cannot be avoided. For quality management in human assessment, assessment methods should be reviewed and revised in order to reduce effects of subjectivity such as assessment biases. It is important to revise

<table>
<thead>
<tr>
<th>Table 2. Action-Based Learning and Testing Symmetry Analysis (ITSS Case).</th>
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<tbody>
<tr>
<td>content ID</td>
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<tr>
<td>learning content items</td>
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<td>total learning activities</td>
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<td>testing content items</td>
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<tr>
<td>total testing activities</td>
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<tr>
<td>activity symmetry</td>
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</table>
quality continuously, supported by systems and methodologies. The competency semantics model can be applied for quality management in human assessment called assessment event analysis (AEA). Table 3 shows the framework of AEA for the example assessment case of a communication skill.

At the top of the table, a targeted competency definition and assessment event are set from the viewpoint of the competency semantics model. At first, contents of the competency definition are analyzed along with the competency semantics model. A communication skill definition is divided mainly into two parts: essential unit and scenario unit. Each unit is analyzed in more detail. The next column sets the property/element along with the competency semantics model.

Secondly, assessment events for the communication skill are also analyzed based on the competency semantics model. Assessment events are shown in the columns “ae01” and “ae02” as examples.

At last, competency definition and assessment events are compared in order to figure out gaps. The gaps are indicated in the final column.

5.2 Results of assessment event analysis

In Table 3, a communication skill is analyzed as an example. The communication skill definition in ITSS consists of 3 sentences.

1) To communicate to various members using basic communication methods and effective communication methods through interviewing and talks.
2) To exchange information frequently through presentation with its techniques, documentation, media selection and persuasion with its methods in order to make mutual understandings.
3) To organize, analyze and retrieve information through situational communication, situational understanding, and usage of meeting techniques.

<table>
<thead>
<tr>
<th>property/element</th>
<th>competency definition</th>
<th>ae01</th>
<th>ae02</th>
<th>gap (before)</th>
</tr>
</thead>
<tbody>
<tr>
<td>meaning</td>
<td></td>
<td></td>
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<tr>
<td>information</td>
<td></td>
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</tr>
<tr>
<td>essential unit</td>
<td>verb 1. communicate</td>
<td></td>
<td></td>
<td>verb[1(ae01,ae02), 2(ae01)][3(-)]</td>
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<tr>
<td></td>
<td>2. exchange</td>
<td></td>
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<tr>
<td></td>
<td>3. a. organize/ b. analyze/ c. retrieve</td>
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<td></td>
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<tr>
<td>object</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1. others</td>
<td></td>
<td></td>
<td>object[1(ae01,ae02), 2(ae01)][3(-)]</td>
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<tr>
<td></td>
<td>2. information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. information</td>
<td></td>
<td></td>
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<tr>
<td>meaning</td>
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<tr>
<td>information</td>
<td>tool 1. a. basic communication methods/b. effective communication method</td>
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<tr>
<td>scenario unit</td>
<td>2. a. presentation technique/ b. persuasion method</td>
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<td></td>
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<tr>
<td></td>
<td>3. meeting technique</td>
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<tr>
<td>process</td>
<td>1. a. interview/b. talk</td>
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<tr>
<td></td>
<td>2. a. presentation/ b. documentation/ c. media selection/ d. persuasion</td>
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<tr>
<td></td>
<td>3. a. situational communication/ b. situational understanding/ c. usage of meeting technique</td>
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<tr>
<td>purpose</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>2. mutual understanding</td>
<td></td>
<td></td>
<td>purpose[2(ae01)]</td>
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<tr>
<td>condition</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1. to various members</td>
<td></td>
<td></td>
<td>condition[1(ae01)] [2(-)]</td>
</tr>
<tr>
<td></td>
<td>2. frequent demonstration</td>
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<tr>
<td>outcome</td>
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<tr>
<td></td>
<td>1. closing successes</td>
<td></td>
<td></td>
<td>outcome[1(ae01)]</td>
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</table>
In this case, two assessment events (ae) for the ITSS communication skill are set as examples: ae01, supervisor assessment by check list; ae02, e-Learning course completed. Both assessment events 01 and 02 only match some part of the competency definition. This means that persons are not correctly judged about their communication skill in the ITSS through only the assessment events (ae) 01 and 02.

In ae01, the aspects of “1. communicate with others” and “2. exchange information” in the essential unit (verb and object) are dealt with ([1(ae01), 2(ae01),3(ae03)]). In ae02, the aspect of “1. communicate with others” can be assessed ([1(ae02)]). The aspect of “3. organize/analyze/retrieve information”, however, cannot be assessed in either of the assessment events ([3(-)]). This status is shown in the “gap” column in a coding manner.

In the case of “tool”, ae01 can assess “1.a. basic communication method”, “1.b. effective communication method” and “2.a. presentation technique”, but it cannot assess tool usages of “2.b. persuasion method” and “3. meeting technique ([2b(-),3(-)])”.

In the case of “process”, ae01 can assess “1.b. talk”, “2.a. presentation technique”, “2.b. documentation”, “2.d. persuasion”, but it cannot assess some parts of the process, “1.a. basic communication”, “2.c. media selection”, and “3. meeting technique ([1a(-),2c(-),3(-)])”.

In the case of “purpose”, ae01 covers “2. mutual understanding”. In the case of “condition”, ae01 covers the definition of “1. to various members” by “to difficult persons(grumpy)”, but “frequent demonstration” is missed (condition [1(ae01),2(ae04)]). In ae02, outcome of the skill demonstration consequence is assessed as human assessment, but this is a different aspect from the definition in ITSS (outcome [ ] [1(ae01)]). So this aspect will not influence the ITSS assessment, but it will be able to use it in another assessment.

Based on the results of the assessment event analysis, ae01 is revised, ae03 and ae04 are added, and ae02 is deleted (Table 4) for the communication technology skill in ITSS. The ae03 is designed as a document analysis; several documents were exchanged with their stakeholders for the purpose of producing a request for proposal (RFP) and the assessed subject’s skill is evaluated. The ae04 is designed as 360 degree evaluation, in which stakeholders are asked about the assessed subject’s performance in each IT system development process.

Table 4 clearly shows that the gap (revised) is re-
duced compared to Table 3.

6. Conclusion

In this paper, existing technological specifications and projects of competency information were reviewed, and then the need for semantics information on competency was pointed out. ISO/IEC 24763 was the first semantics model for competency information as the conceptual design level. A Japanese national institute pushed the development of a semantics information model for competency, and an industrial association developed a data specification for the semantics model.

On the other hand, quality in e-Learning has been developing well from the viewpoints of closed system architecture or organizational quality management such as ISO 9000. But concepts or systems for dealing with learning quality have been lacking, in spite of getting some attention\(^\text{19}\).

After introducing the competency semantics model, methodologies of quality management were discussed for effective usage of the model. The semantics information model was determined to be complicated, and it was hard to find suitable applications and benefits of the model. It was thought that the competency semantics model would provide good solutions for e-Learning quality improvement and management from the aspect of quality engineering.

Then two methodologies of quality analysis were explained and proposed with empirical data; the methodologies were activity-based learning and testing symmetry analysis (LT symmetry analysis) and assessment event analysis (AEA). Both analyses were based on the competency semantics model.

LT symmetry analysis could provide detailed information for features of learning and test contents. It also figured out matches between learning and testing. Test score was used for quality assurance. If tests did not match with learning content, the test score could not be used for quality assurance. Furthermore, tests should directly reflect onto learning content for learning quality.

All learning has to connect with competency development, so human assessment needs a rational relationship to learning whether or not the relations are direct or indirect. AEA could provide detailed information for features of the competency definition and assessment events for target competency. It also was able to figure out matches between the competency definition and assessment events. Human assessment should be made correctly for human development including organizational development. AEA could be used to get greater accuracy in human assessment and its events for target competency.

These methods were applied to only one skill set and its learning and assessment contents in this study, so the methods should be checked for applications to other skill sets or learning and assessment contents. And here, the methods were used only for analysis. They should be used in the future to improve results of learning through a quality management cycle.

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