The "i Competency Dictionary" Framework for IT Engineering Education

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***Abstract*—Information technology (IT) engineering education in Japan has a major issue in linking IT education in universities with IT industry requirements. The IT world is changing very rapidly now and the academia-industry linkage is becoming difficult and divergent. In this paper, the authors describe the "i Competency Dictionary" (iCD) framework developed and announced by Information-technology Promotion Agency (IPA), a Japanese government organization in 2015. IPA developed this iCD framework for IT user organizations and IT vendor companies for their human resource development. Since its announcement, iCD has been expanding very rapidly within Japanese IT industries and the framework is becoming a reference in many IT organizations outside Japan. In the meantime, universities and educational organizations are starting to use iCD to develop and evaluate their curricula since it contains rich industry requirements reflecting today's rapid IT changes. The authors believe that iCD can contribute much to educational areas and they illustrate examples of the iCD successes in academic circles.**

Keywords—i Competency Dictionary, task dictionary, skill dictionary, task×skill matrix, human resource development, competency, educational organizations

I. Introduction

Information technology (IT) industries are changing very rapidly due to the introduction of new technologies and services such as the internet of things, cloud services, big data, and artificial intelligence. Under these environments, an IT company or an IT department within a company must grow its human resources (HR) rapidly and flexibly to respond to new changes.

In this paper, the authors focus on the "i Competency Dictionary" (iCD) framework announced by the Information-technology Promotion Agency (IPA) in June of 2015 for IT human resource development in IT organizations [1,5]. A 'human resource' within an organization (sometimes called "an organization member") is the source of organization capability since it provides a 'competency' for business execution. Other major frameworks such as the Skills Framework for the Information Age (SFIA) [2] or European e-Competence Framework (e-CF) [3] are all skill-based frameworks that require people to acquire necessary skills and to utilize them on their jobs. However, from our experience with skill-based frameworks such as the IT Skill Standards (ITSS) [4], we believe these frameworks cannot catch up with the rapidly changing IT environment since selected skills do not always match to the needs for accomplishing a job. Furthermore, the skill selection requires trial and error modification. In contrast, the iCD framework contains the task dictionary and the skill dictionary that innovatively accomplish task allocations for organization members to develop their competencies, thereby enhancing an organization's capability. Tasks of an organization and its organization members directly indicate jobs they must do now and in the future so they can easily understand what they must do today. Skills associated with tasks are available, but these are secondary in support of tasks.

On the academic side, educational organizations and universities usually avoid industry needs since they develop their curricula very academically. Today, however, these institutions must reconsider their IT curricula since industry needs graduates that are "ready-to-go" in the workplace. Hence, academic organizations are now interested in iCD to design modern IT curricula to develop students with current industry requirements since iCD reflects such needs. To address these issues, the authors show how iCD can be useful to academic organizations in developing their IT curricula.

II. The iCD Framework

The iCD framework consists of the task dictionary and the skill dictionary (Fig. 1). The task dictionary is the collection of tasks required for an IT business; the skill dictionary is the collection of IT skills required to perform specific tasks. In the iCD framework, a task identifies a function of the IT organization. In other words, a task is a specific job while a skill means the ability to handle knowledge. The iCD framework contains many necessary elements from three previous skill standards in Japan. These include the Information Technology Skill Standards (ITSS), the Embedded Technology Skill Standards (ETSS) [6], and the Users' Information Systems Skill Standards (UISS) [7]. Moreover, the iCD framework refers to process standards such as the Software Life Cycle Processes (SLCP) – the Japan Common Frame 2013 – and bodies of knowledge such as the Project Management Body of Knowledge (PMBOK), the Software Engineering Body of Knowledge (SWEBOK), and the Software Quality Body of Knowledge (SQuBOK).

The most distinctive characteristics of the iCD framework are to allocate tasks to organization members based on their roles and to evaluate the task performances with scores from 0 to 4 leveling at regular intervals. Since allocated tasks are equal to their daily jobs, organization members can accept allocated tasks naturally. As mentioned previously, conventional methods of HR development are to allocate skills to organization members and to force them to "skill up" through studying, taking certification examinations, or attending education classes. However, problems exist with this method; having high-level skills does not always guarantee having high-level task execution or performance. Moreover, a person's skill allocation does not always match with a daily job. Hence, allocated skills reduce to a meaningless management matter. In HR development by the iCD framework, the first thing organizations do is to allocate tasks, not skills to organization members. Since these members understand the allocated tasks, real HR development can begin based on tasks.

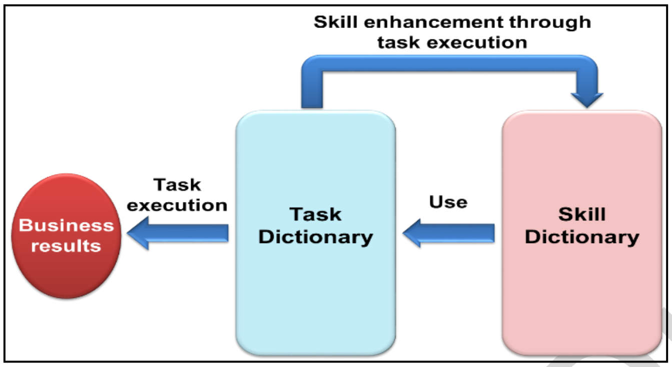

Figure 1: iCD Structure

The iCD framework can visualize the task execution capability by the member's task performance evaluation results of assigned tasks. A statistical analysis by department or by role helps managements to understand the organization status of task execution capability.

Each organization defines its own task requirement for its business processes by extracting activities from a list of tasks contained in the task dictionary. Therefore, its own task definitions are different depending on an organization's characteristics. An organization can prepare its own tasks by simply selecting tasks from the task dictionary. Small and medium sized companies with insufficient human power can implement the iCD framework through efficient and labor saving selection operations. Large companies can also easily implement the iCD framework not only for a whole company, but also for a department or a project within the company.

III. Task and Skills Dictionaries

The task dictionary is a four-layer structure (Fig. 2). A task breaks down in detail from the first layer to the second layer and to the third layer. Organization members evaluate the task performance typically based on allocated third layer tasks. The fourth layer (called "evaluation items") helps to understand the meaning of the third layer task. Organization members may evaluate task performance in the second layer rather than in the third to avoid much detail.

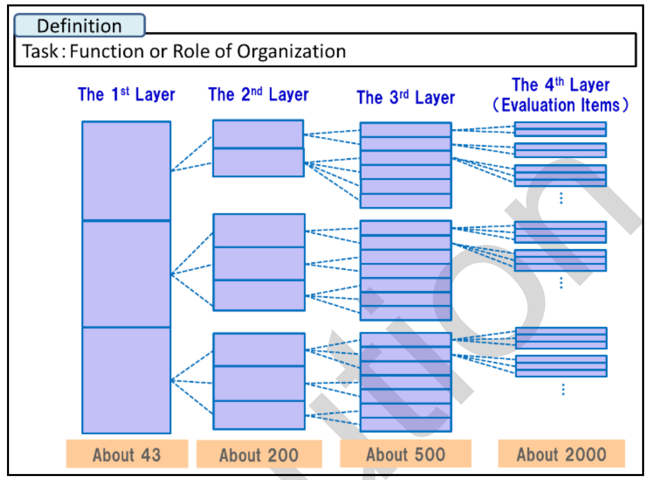

Figure 2: Task Dictionary Structure

Appendix A shows 43 tasks in the first layer. This diagram indicates tasks located from the upper to the lower on the left; these are tasks in the system development process. Tasks on the right side are several supporting tasks.

The skill dictionary is also a four-layer structure (Fig 3). The construction of the skill dictionary started from the integration of the fourth layer. The iCD framework calls the fourth layer the body of knowledge (BOK) and the construction started the collection of BOKs from various BOK sources. The BOK sources are the old Skill Standards in Japan such as ITSS, UISS, ETSS, computing curriculum standards J07 [13], ITIL, the business analysis body of knowledge (BABOK), SWEBOK, and the strategy and analysis body of knowledge (SABOK). These BOKs integrate into the third level (skill item), then integrate into the larger second level (skill classification), and then into the first level (skill category) in the same manner.

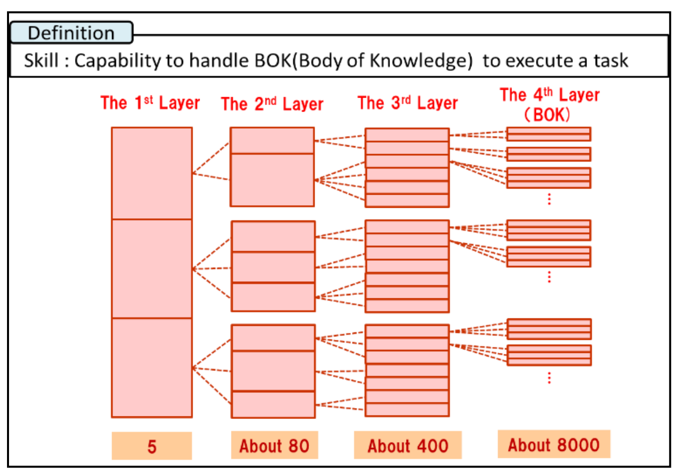

Figure 3: Skill Dictionary Structure

Appendix B shows the first and second layers of the skill dictionary. Five items in the first layer (skill category) are technology, methodology, related knowledge, IT human skill, and specific skills (optional). The second layer (skill classification) consists of 79 items.

IV. HR Development Processes by Task Dictionary

The process of HR development by the task dictionary consists of following four steps.

Step1: Biz Strategy & Task Analysis

An organization analyzes its own task requirements corresponding to its business strategy by referencing the task dictionary.

Step2: Tasks & Roles Definition

An organization drafts its own tasks to meet its business strategy from the task dictionary. An organization includes not only 'as-is' tasks but also 'to-be' tasks for its future business. The consideration of 'to-be' tasks is quite important to realize the business strategy for this process.

Step3: Tasks & Roles Determination

An organization refines its own draft tasks by taking task feasibility into consideration. The organization confirms its tasks and roles after several trials by setting the role for each task and updating it. Moreover, this process assigns required roles and responsible tasks for each organization member.

Step4: Evaluation

An organization starts this process based on its own defined tasks and its task assignment to each organization member. Each organization member evaluates the assigned task performance in five levels, from level 0 to level 4. Organization members can evaluate task performance for the third layer or the second layer depending on the requirements of the evaluation detail. Typically, this occurs at the end of a fiscal year. Organization members discuss and adjust the task evaluation result with their managers. Then, the manager approves the final evaluation result, which departments analyze by roles.

Even after the process begins, adjustment and improvement is possible so organization members feel comfortable using the process by avoiding the separation from actual daily business activities. The process goes back to the plan-do-check-act (PDCA) continuous improvement cycle for the next fiscal year. In this process, after reviewing a task performance level evaluation of all organization members, the organization assesses and fixes the task performance of each member.

Organization members discuss with their manager the status of the task performance and the future direction to determine the future task performance objective. They also determine the task they must enhance and its performance target of the next fiscal year. To achieve higher target results in the next fiscal year, they will try to accumulate the target task experience and enhance the skill for the task. At the end of the next fiscal year, they will identify the improvement status of their target and demonstrate the contribution to the organization if they made progress.

Since the summary of the evaluation by department shows the reality of the business process competency of a department or a member, executives and HR departments of an organization can construct an efficient HR development strategy. The evaluation result of each organization member and the aggregation by a department or a role makes the organization status visible. This information is useful beyond the HR development.

V. Capability Enhancements by Task×Skill Matrix

An organization can enhance its capability by augmenting competitive advantage tasks against competitors in addition to the organization's member HR development. Organizations should select competitive advantage tasks to meet their business strategy.

Once an organization determines its competitive advantage tasks, it can identify the corresponding skills by the Task×Skill Matrix. Fig. 4 shows a portion of a Task×Skill Matrix that can contain up to 500 vertical third-level tasks from the task dictionary and up to 400 horizontal third-level skills from skill dictionary. The circles within the matrix indicate the corresponding skill required for the task execution.

For example, in the Task 3 row, there are circles under Skill 1 and Skill 6. This means the organization should require these skills to achieve Task 3. Based on these relations between tasks and skills, an organization can identify skills needed for competitive task advantages of a specific task. Hence, a company can enhance its organizational capability and the competitiveness as well by using the task dictionary, the skill dictionary, and the Task×Skill Matrix.

Skill List

Task List

	Skill1	Skill2	Skill3	Skill4	Skill5	Skill6	Skill7
Task1	○		○				
Task2		○			○		○
Task3	○					○	
Task4			○				
Task5				○			○
Task6		○			○		

Figure 4: Task x Skill Matrix Image

VI. iCD Implementation in Industry

The iCD framework has almost a thousand real implementation cases in Japan. Focused workshops supported by IPA have been very effective in Japan. These workshops assemble several companies and guide them on ways to implement iCD to each company over three months. Approximately a hundred companies have joined these workshops and interest is growing steadily. Most participants are small and medium-sized companies. This trend shows that the workshops have been effective in promoting iCD in these companies.

Some testimonies from companies participating in the workshops include the following.

- iCD increases the number of employees that fit into their business strategies.
- iCD motivates employees by making them understand what to do for their companies.

- iCD identifies clearly the strengths and weaknesses of employees.
- iCD is useful to construct an employee HR development framework in a short period of time, which would otherwise be impossible.
- iCD promotes mid-career employment effectively since it can reflect candidate experiences through by iCD tasks.

The iCD industrial implementations have shown many effects. The following are two examples of iCD quantified effects.

Company A: Sales volume increased

Company A is a software development company with 50 engineers. There are five teams in the company. The iCD implementation started from joining iCD workshop by IPA in 2015. Teams 1 and 2 had 80% members joined the workshop, teams 3 and 4 had 60% members joined, and team 5 did not join the workshop. Company A implemented iCD and it has been tracing the team performance by sales volume. Teams 1 and 2 have shown 50% and 225% sales volume increase, respectively, from 2015 to 2017. The reason for these sharp increases is considered due to their team based iCD implementation effort. Team 3 showed flat sales change and team 4 showed 50% sales decrease from 2015 to 2017. The reason is likely their iCD implementation effort was not team based but individual based. Team 5 showed substantial sales decrease by ignoring iCD.

Company B: Engineer price up

Company B provides outsourcing services with about 500 engineers. They implemented iCD in 2015. Before that, they did not have the price list of engineers; business negotiation with engineer fees were based on individual personnel expenses. After iCD implementation, they could define the price table based on roles and levels. From this table, they developed each employee's price list depending on role and level; business negotiations can now be based on the employee's price list. Among engineers who could improve their task level, 80% of them received higher engineer prices since 2016.

VII. ICD IMPLEMENTATION IN ACADEMIA

Although implementation of iCD in Japanese industries has been progressing successfully and has expanded as intended, iCD implementation is also progressing at academic organizations. IPA welcomes this trend since these phenomena demonstrate iCD's wider acceptance. Two examples of iCD implementations at academic institutions provide a sense of use. The first case is the Advanced Institute of Industrial Technology (AIIT), a graduate school for advanced professional education [9,10,11]; the second case is the Electronics Development Computer College (EDC), a professional school located throughout Japan.

A. The AIIT Case

1) Introduction

Founded in April of 2006, the Advanced Institute of Industrial Technology is a public graduate school in Tokyo. It offers curricula to develop advanced specialists for working professionals and graduate students. AIIT has an information systems architecture program for information systems architects that enjoy success in the information systems development field. It also has an innovation design and engineering program that develops specialists capable of creating and reasonably developing products and services that maximize consumer benefits. IPA experiences with the information systems architecture program are informative.

2) Issues

After years of providing IT curricula, adding new subjects, replacing teachers, and changing topics through teacher's re-orientation, AIIT has found the following issues.

① Duplication of knowledge items cross multiple subjects;

② Lack of knowledge that subjects should provide;

③ Inability of students to identify precisely the knowledge they acquired.

3) Solution

Prepare a curriculum based on CC2005 [12] or on J07 [13] by the Information Processing Society of Japan (IPSJ) as a reference. However, since AIIT is a graduate school for IT specialists, much of the knowledge selected from these references may not provide necessary elements consistent with practical use.

In this regard, AIIT used the iCD Skill Dictionary to show relevant IT knowledge items and knowledge level (levels 2-4) in the syllabus of a subject. Initially, AIIT tried to define new knowledge items by themselves if they believed there was an iCD knowledge mismatch. However, they quickly realized that this change needed much additional effort to validate the transition from their original knowledge item definitions. As a result, AIIT now depends on iCD without any modification since iCD enjoys strong public consensus as well as being a product of the Japanese government for its people.

Because of its syllabus updates and additional syllabus adjustments, AIIT has solved issues ① and ② whereby students are now able to accomplish their course plan precisely while understanding the course results objectively. Hence, AIIT also resolved issue ③. AIIT also implemented a new student evaluation method that bestows a special title for excellent students to honor them for having distinguished performance.

4) Future

In the future, AIIT plans to promote the iCD system developed and supported by IPA for students to use iCD directly by themselves. AIIT also plans to join an iCD function open to public that shows linkages between iCD tasks and iCD skills in addition to educational courses provided by educational organization companies. Because of this function, AIIT can improve public awareness of its curriculum and its school.

B. The EDC Case

1) Introduction

Founded in Hokkaido in 1968, the Electronics Development Computer College now has ten schools in major cities throughout Japan. Each year 1500 students graduate from EDC; 70,000 graduates are now successful in diverse IT industries. The educational area of EDC includes systems, multimedia, games, business, and medical information to meet current requirements and needs in high evaluation industries.

2) Issues

EDC had been having the following two areas of issues regarding their curriculum.

① How to meet industry needs?

② How to solve EDC curricular design problems?

EDC was in a serious situation because their curriculum was unable to meet the requirements of industry. The EDC curriculum only indicated skills acquired from subjects. However, industry strongly wanted to know what EDC graduates can do. That is, industries were not interested in what kind of knowledge graduates had. They wanted to know what EDC graduates "can do" exactly. Unfortunately, the EDC curriculum did not meet these requirements.

EDC realized that it could not develop an ideal curriculum only by listing skills to subjects in a curriculum. EDC wanted to construct its curriculum in a top down manner by defining what type of person the subject could develop or what students could do after finishing a subject. (EDC calls this "the education attainment target" for its purposes.) However, EDC teachers were not confident enough to define "the education attainment target" for the curriculum.

3) iCD Solution

To solve issues ① and ② above, EDC understood that a common theme could work. That is, EDC must design a curriculum based on a "can do" theme in a top down manner. For this, EDC believed that the iCD Task Dictionary covered all "can do" industry listings; the EDC team developed each subject and the flow of subjects by identifying which iCD tasks matched a given subject. Then, EDC designed the curriculum by dividing subjects into two categories (1) identifying the basic subjects aimed to acquire skills, and (2) additional core subjects aimed at fulfilling the "can do" list.

4) Future

EDC does not use the iCD Skill Dictionary in a direct manner. However, it does plan to construct a mechanism to evaluate student performance using the Skill Dictionary. This is because evaluating people by a "can do" method is rather difficult while they are still students. EDC believes skill-based student evaluation is appropriate and it prefers to extend subjects in curriculum reflecting future Task Dictionary expansion.

VIII. CONCLUSION

The maintenance of iCD content is extremely important to keep iCD an up-to-date framework. Hence, iCD has made many updates with a new version announced each year to keep up with new IT technology and application areas. The iCD framework already contains cloud services, big data, and security areas and it contains an internet-of-things area in 2017 version.

Implementation of the iCD framework is rapidly expanding in Japan. The task dictionary of iCD is contributing to the enhancement of organization capability. Organizations need not be IT vendors; they could be any company that has an IT department. Since most companies have an IT department, the extent of possible users includes all industries. Additionally, organization sizes range from small to large so an IT department can assume the role of an organization. That is, the iCD framework is applicable to any organization of any size, any type, or any industry, including educational institutions. Consequently, the number of target organizations is very large.

By using the task dictionary, organization members know their responsible tasks. Since tasks from the task dictionary are common, organization members can explain their tasks across organizations in a common language. The skill dictionary is useful not only for an individual skill-up; it is also useful for a university or an educational institution in constructing their curriculum course development. The skill expression becomes a common language based on words from the skill dictionary of iCD framework.

The iCD framework is useful not only for HR development, but also for business reengineering processing and HR hiring. In addition, since IPA developed the iCD framework as a government agency, public acceptance of iCD in Japan is large. The global collaboration between the IPA iCD framework and overseas organizations are also progressing. The iCD framework expects to receive greater attention in global HR development. Indeed, the iCD framework should become a vital tool for organizations beyond Japan.

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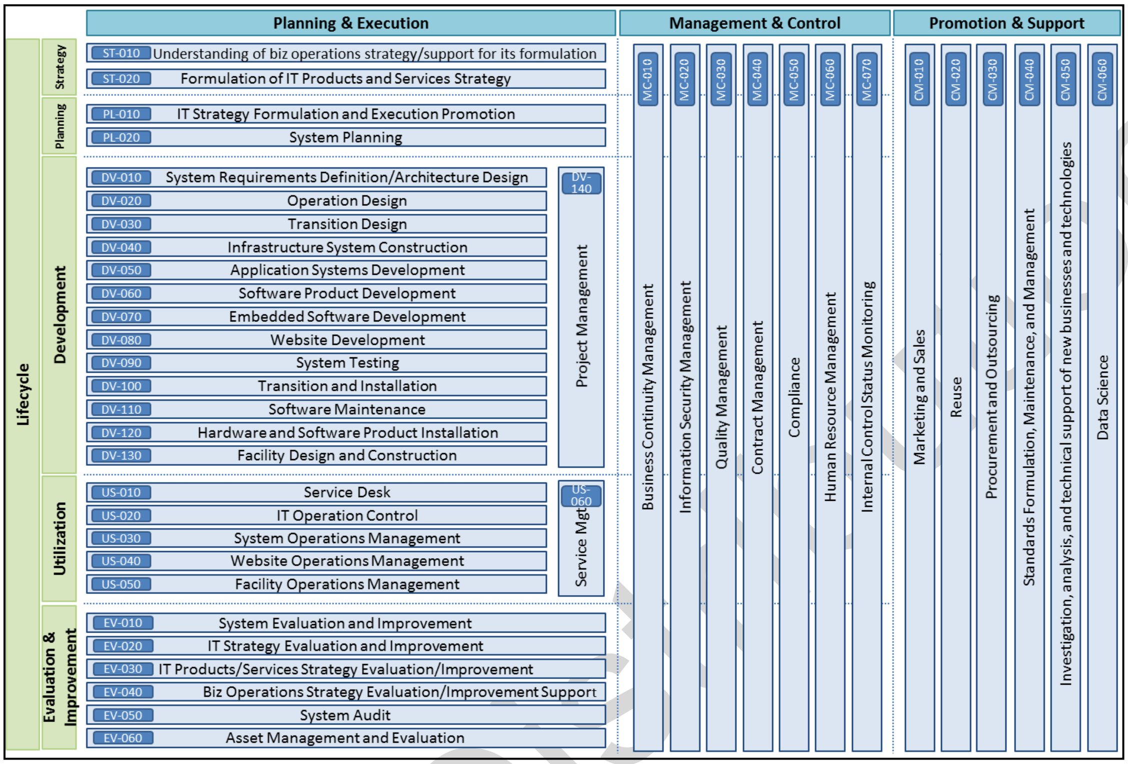
Appendix A: First Layer of Task Dictionary



Appendix B: First and Second Layer of Skill Dictionary