Analysis of Computing Curriculum Standard J07 using ICT Common Body of Knowledge

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Abstract

Information Processing Society of Japan (IPSJ) has announced the Computing Curriculum Standard J07 which is compatible with the Computing Curricula 2005 (CC2005) Series proposed in the United States. Both J07 and CC2005 are composed of five major domains, CS, CE, SE, IS and IT, each of which is developed by different community so that relationship among these domains is not concrete. In this paper, we analyze each body of knowledge (BOK) of the domains and map them into the ICT common body of knowledge (ICTBOK). We estimate the degree of importance and the requirement level in terms of the 155 ICTBOK areas for each domain by utilizing the mapping. As a result, the relationship among the domains is clarified. We also compare the analysis result with the requirement data collected from 58 business persons.

1. Introduction

Quality assurance of higher education is a global trend. To this end, Japanese universities are building systematic education system. Currently many universities and departments have their own diploma policy to demonstrate the ability of their graduates.

The Japanese ministry of education has built a public quality assurance framework. The framework is composed of the standards for establishing universities, the establishment approval system, and the periodical accreditation system.

Industry and the Japanese ministry of industry both realize that ICT (Information and Communication Technology) is necessary for global competition. The Japanese government and the local governments want to increase business efficiency by developing and operating digital government. Large number of high level ICT professionals is necessary to achieve these goals.

The Information Processing Society of Japan (IPSJ) has supported these activities from many perspectives. Among such activities, IPSJ announced the Computing Curriculum Standard J07 [4] as a guideline for college level ICT education. J07 is essentially compatible with the Computing Curricula 2005 (CC2005) [3] developed by ACM, IEEE Computer Society and AIS. Considering the diversity of the computing disciplines, the following five major domains are defined both in J07 and CC2005.

- CS: Computer Science
- CE: Computer Engineering
- SE: Software Engineering
- IS: Information Systems
- IT: Information Technology

Each domain of J07 and CC2005 is developed by different community for historical reasons so that the body of knowledge (BOK) of each domain is described using different terminology. As a result, relationship among these domains is not concrete and clear not only for the society including industry and government but also for faculty members of ICT departments. This situation is not desirable for many stakeholders of the computing curriculum.

In this paper, we analyze the BOKs of the five domains of J07 to map them into the ICT common body of knowledge (ICTBOK). ICTBOK is composed of 6 categories, 23 fields and 155 areas; and covers a wide range of knowledge and skill required for ICT professionals. Thus clear and concrete analysis becomes possible in order to clarify the relationship among the five domains.

Detail of ICTBOK is described in Section 2. Structure of J07 is summarized in Section 3. We shall overview the analysis plan in Section 4. In Section 5, we map BOK of each domain into ICTBOK. Then we estimate the degree of importance of the 23 fields of ICTBOK for each domain. The requirement level of each ICTBOK area is also estimated for each domain.

We are currently executing the J07 follow up survey project which is composed of achievement and requirement surveys. Through the achievement survey, we collect achievement levels of the 155 areas of ICTBOK from department and graduates of ICT colleges. The requirement survey is carried out for business persons of ICT industry of various positions [5]. Through the requirement survey, the requirement levels and the degrees of importance of the 155 areas are collected in order to analyze the detailed requirement. The analysis of the J07 domains is a part of this survey.
project to clarify the relationship among various activities of education and professional development in ICT.

The analysis result of the J07 follow up survey will be distributed to the survey contributors in order to promote mutual understanding among university, industry and government. It will also be utilized to further improve the J07 curriculum standard.

2. ICT Common Body of Knowledge

ICT common body of knowledge (ICTBOK) is developed to uniformly represent knowledge and skill of ICT professionals belonging to various job categories and levels [1]. The ICTBOK can also be used to represent outcomes and requirement of ICT education program. ICTBOK is composed of 7 categories, 23 fields and 155 areas. Analysis of J07 is carried out using the common form representing ICTBOK so that comparison among the analysis results becomes possible.

IPA (Information Technology Promotion Agency) of the Japanese government announces three types of skill standards for ICT professionals [2]. They are (1) ITSS (skill standards for IT professionals) for people working for IT services industry, (2) ETSS (embedded technology skill standards) for embedded software development engineers, and (3) UISS (user’s information system skill standards) for information system users. We have analyzed the three skill standards and have defined ICTBOK. ICTBOK also covers the teaching domain of college level ICT education by analyzing and integrating J07 and CC2005.

Table 1 represents categories and fields of ICTBOK.

Table 1 Categories and Fields of ICTBOK

<table>
<thead>
<tr>
<th>Category</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations of Computer Science</td>
<td>Fundamental Theory (7)</td>
</tr>
<tr>
<td></td>
<td>Mathematics, Applied Mathematics (5)</td>
</tr>
<tr>
<td></td>
<td>Computer Architecture (9)</td>
</tr>
<tr>
<td></td>
<td>Hardware (7)</td>
</tr>
<tr>
<td></td>
<td>Operating System (5)</td>
</tr>
<tr>
<td>Media, Human Computer Interaction</td>
<td>Multimedia Data Processing (8)</td>
</tr>
<tr>
<td></td>
<td>Human Interface (3)</td>
</tr>
<tr>
<td></td>
<td>Usability (2)</td>
</tr>
<tr>
<td></td>
<td>Intelligent System (6)</td>
</tr>
<tr>
<td>Network and Security</td>
<td>Telecommunication System (9)</td>
</tr>
<tr>
<td></td>
<td>Computer Network (6)</td>
</tr>
<tr>
<td></td>
<td>Web Technology (8)</td>
</tr>
<tr>
<td></td>
<td>Security (6)</td>
</tr>
<tr>
<td>Software Development</td>
<td>Database (10)</td>
</tr>
<tr>
<td></td>
<td>Algorithm and Data Structure (5)</td>
</tr>
<tr>
<td></td>
<td>Computer Programming (5)</td>
</tr>
<tr>
<td></td>
<td>Software Engineering (11)</td>
</tr>
<tr>
<td>Information System</td>
<td>Project Management (6)</td>
</tr>
<tr>
<td></td>
<td>System Operation and Evaluation (8)</td>
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<tr>
<td>Business</td>
<td>Business and Administration (8)</td>
</tr>
<tr>
<td></td>
<td>Technical Communication (5)</td>
</tr>
<tr>
<td></td>
<td>Society and Ethics (4)</td>
</tr>
<tr>
<td>Competences</td>
<td>Competences (12)</td>
</tr>
<tr>
<td>Others</td>
<td>Additional fields or areas can be defined by the users, if necessary.</td>
</tr>
</tbody>
</table>

Figure 1 Conceptual Relationship of J07 Domains

J07 is composed of six domains, CS, CE, SE, IS, IT and GE [4]. Here GE is a curriculum standard for general ICT education for non-ICT students. Other five domains correspond to CC2005 domains with some modification to adopt situation in Japan. Conceptual relationship of the domains is illustrated in Figure 1.

Curriculum of Japanese university is typically composed of three parts: one-year general education, two-year technical education for specific major domain, and one-year graduation research project. J07-GE is designed for non-ICT students as a part of their general education. Other J07 domains are designed for ICT students as a part of their technical education. Since ICT discipline is rapidly growing and J07 is proposed as a guideline for ICT curriculum development, IPSJ does not want to strictly “define” ICT curriculum. Instead, J07
defines core units for one-year technical education in ICT. Although ICT departments are expected to choose one of the five domains, they can freely design the remaining three-year part of their curriculum.

Among the domains of J07, CS, CE and IT have the same structure. For example, the BOK of the CS domain (J07-CSBOK) is composed of 15 knowledge areas and 138 units. Minimum core coverage time, topics and learning objectives are defined for each unit. If the minimum core coverage time of a unit is more than 0, the unit is called a core unit. The expected outcomes of the student are defined as learning objectives. The topics describe the teaching topics of the unit.

The structures of SE and IS are different from the above.

J07-SEBOK is composed of 17 knowledge areas and 297 units. J07-SE is based on SE2004 [3] except that core time is not defined for each unit. Instead, each unit is assigned to some course whose syllabus contains the weekly plan. The weekly plan also contains the learning objectives for the corresponding unit.

Main component of J07-IS is the learning units (LU). J07-IS is based on IS2002 [3] developed by AIS. 209 LUs are defined in J07-IS. Among them 108 are the core LUs. LUi#, level, teaching and learning objectives are defined for each LU. The level of a LU is between 0 and 5; 0 stands for “does not know”, 1 for recognize, 2 for explain, 3 for utilize, 4 for apply, 5 for proficient.

4. Analysis Plan of J07

ICTBOK has three-level hierarchical structure composed of category, field and area. We collect the achievement and requirement levels of each area through the J07 follow up survey. The achievement and requirement levels are defined as shown in Table 2. Basically, the levels are defined according to the Bloom’s taxonomy. Level 2 is the level to explain the knowledge area or to execute the knowledge with detailed instruction. Level 3 of the skill is the level to execute the area with simplified instruction. Typically extensive training at a laboratory is required to achieve level 3 while learning or exercise at a 15-week course is required to achieve level 2. Education to earn a master degree is usually expected to achieve level 4.

We also collect the weight of each area representing the degree of importance of the area through the requirement survey.

The analysis of J07 is carried out in order to estimate the requirement level and the weight of each ICTBOK area for each domain of J07.

Among the domains of J07, CS, CE and IT have the same structure. Thus we shall explain the common analysis plan for these three domains. The remaining two domains, SE and IS, will be discussed in Section 5.

Assuming the above BOK structure explained in Section 3, we first make correspondence between the core units and the areas of ICTBOK. If a unit corresponds to a single area, the core coverage time of the unit is assigned to the area. In case that multiple areas correspond to a unit, the core time is proportionally divided among the areas considering the learning objectives and topics of the unit.

When we have built the correspondence, the weight of each area is computed by the sum of the core times of the area. The weight of each category and field can be computed similarly.

The requirement level of each area is basically determined from the learning objectives of the corresponding core units. The learning objectives are described using various verbs summarized in Table 3. Knowledge and skill requirements can be evaluated by these verbs. However, the requirement level is set to zero, if the assigned core time is zero since the teaching of the area is not guaranteed. The requirement level is set to one if the assigned core time is an hour or less, since it is expected to be difficult to teach an area within an hour so that students can explain the area.

5. Analysis Result of J07 Domains

Figure 2 illustrates the distributions of the importance levels (weights) of the fields of the J07 domains. The weights of the fields are normalized so that the sum of the weights is equal to 100% for each domain.
Table 4 represents the numbers of ICTBOK areas for each J07 domain categorized by knowledge or skill requirement levels. No area has a requirement level 3 or more because level 3 is typically achieved by extensive training through graduation research project which is outside of the scope of J07. Thus the main part of the requirements is represented by the number of level 2 areas.

### 5.1. Computer Science (CS)

Analysis of J07-CS is carried out as described in Section 4. In Japan, majority of ICT departments teach computer science, which focus on the theory and modeling issues. However, CS is not only a theoretical domain. CS also focuses on computer programming and software engineering as can be seen from Figure 2. The number of level 2 areas is on the average among the five domains.

### 5.2. Computer Engineering (CE)

Analysis of J07-CE is carried out as described in Section 4. CE is the second largest community of ICT departments in Japan. J07-CE focuses on hardware, architecture and embedded software development. Compared with CE2004 [3], software issue is more emphasized in J07-CE. This can be observed in Figure 2 by the weights assigned to software engineering, computer programming, and database. The number of level 2 areas is the second largest among the five domains.

### 5.3. Software Engineering (SE)

Taking the structure of J07-SE, explained in Section 3, into consideration, we assign each week of the J07-SE
courses to ICTBOK areas. The weight of the area is defined by the number of courses. For example, weight of an area becomes 2/13 if two weeks of a 13-week course correspond to the area. The knowledge and skill requirement levels are estimated according to the following criteria.

- Knowledge and skill requirement levels are zero if the area has no weight.
- Knowledge requirement level is one if the weight of the area is less than or equal to 2/13; two if the weight is more than 2/13.
- Skill requirement level is computed in a similar way as the case of knowledge requirement level. The only difference is that the weight is defined by the number of exercises instead of lectures.

J07-SE strongly focuses on the software engineering field as illustrated in Figure 2. This is because J07-SE intends to develop highly skilled software developer. However the number of level 2 areas is the smallest among the five domains.

5.4. Information Systems (IS)

Analysis of J07-IS is carried out using the core LUs. We first assign the every LU to the area. If there are more than one areas corresponding to an LU, the number is proportionally assigned to each area. The weight of each area is computed by the number of core LUs corresponding to the area.

Requirement levels are determined using the following rules.

- Knowledge and skill requirement levels are zero if there is no core LU corresponding to the area.
- Knowledge requirement level of an area is one if the levels of corresponding core LUs are either 0 or 1, two if the level of a corresponding core LUs is 2 or above.
- Skill requirement level of an area is one if the levels of corresponding core LUs are 3, two if the level of a corresponding core LU is either 4 or 5.

Information systems focus on business administration, system operation and project management as well as software engineering. This is because that J07-IS ultimately aims at developing chief information officer (CIO). The number of level 2 areas is on the average among the five domains. However the number of areas having knowledge level 1 is the largest. This shows that J07-IS requires graduates to have a wide range of knowledge as a CIO candidate.

5.5. Information Technology (IT)

Analysis of J07-IT is carried out as described in Section 4. J07-IT is partly similar to J07-IS, but J07-IT focuses on education of computer administrator. This can be observed from Figure 2 by the weights assigned to the fields such as database, security and web technology. Compared with other J07 domains, the weight of each field is more widely distributed. The number of level 2 areas is the largest among the five domains. This implies that J07-IT requires practical knowledge and skill as computer administrators.

6. Comparison with Industry’s Requirement

6.1. Comparison of Importance Level Distribution

As explained in Section 1, we have conducted J07 follow up survey in order to collect and to analyze industry’s requirement in a quantitative manner [5]. Currently 58 business persons with different background joined the requirement survey. Figure 3 illustrates the importance level distribution of 23 fields of ICTBOK. Each importance level is computed by the requirement data collected by the requirement survey. Although the opinions of the business persons are widely distributed, little difference can be found for the importance level
distribution for graduate and undergraduate students. Among the 23 fields, the competences field collects the highest importance. On the other hand, none of the J07 domains mention the requirement for the competences field as can be seen from Figure 2. This is because the competences are out of scope of current J07. However, the Japanese government and JABEE (Japanese accreditation board for engineering education) strongly require competences for Japanese universities.

The competences field is composed of the following 12 areas.

- Ability to act positively
- Ability to set goal and to act
- Ability to listen carefully
- Ability to express one’s opinion
- Ability to analyze current status
- Flexibility
- Ability to keep rule or premise
- Ability to manage stress
- Planning ability
- Ability to influence people
- Creativity
- Ability to understand circumstances

We think that requirement for these areas can be achieved simultaneously while learning other skill or knowledge. Such knowledge or skill may not belong to ICT. However the remaining weight (more than 75%) is assigned to ICT related areas so that it is a reasonable solution to teach competences during ICT education.

The readers can observe that industry wants generic skill as well as ICT-specific knowledge and skill. Such tendency happens because the number of ICT engineers is much more than the number of graduates majored in ICT. For example, the number of ICT engineers is about 1 million in Japan; while the number of ICT graduates is about 10,000 per year which is only 1% of the number of ICT engineers. Thus industry has to hire a large number of non-ICT graduates as ICT engineers.

6.2. Distribution of Distance

We have collected 88 answers from the 58 respondents of the requirement survey. Many of the respondents answered the requirements for both of undergraduate and graduate students so that the number of answers exceeds the number of respondents.

Profiles of the respondents are as follows. 34 respondents are corporate executives or managers, 19 are IT engineers, and 5 are employment section staffs. 38 respondents mainly engage in projects smaller than 1 Million US$ (relatively small size ICT project), the remaining 20 engage in project of more than 1 Million US$. 49 respondents are between the age of 40 and 59, while 8 are younger than 40.

We compare each answer with the requirement of each J07 domain by computing the distance between two requirements. In order to compute the distance, we first compute the importance level distribution of 23 fields of ICTBOK for each requirement data. Next the importance values are normalized so that the sum of the values is equal to 1. The distance of two requirement data is defined by the Euclidean distance of the two vector data.

Figure 4 illustrates the distribution of the distances between the answers and the requirements of J07 domains. The distance category 0.1 represents the interval between 0.1 and 0.2. The remaining categories are defined similarly. Although there are few answers whose distance is less than 0.2 for each J07 domain, more than 73% of the answers have distance less than 0.5 for CS, CE, IS and IT domains. The average distance for SE domain is larger compared with other domains.
because SE strongly focuses on the software engineering field. Although CS is often argued to have a large mismatch from the industry’s requirement, such tendency cannot be observed from the distance distribution. The authors think that this is because that CS places weights on computer programming and software engineering.

7. Conclusion

It is often said that there is a mismatch between industry’s requirement and university’s achievement in ICT education. Our research focuses on this point and aims at clarifying the mismatch. In this paper, we analyze the J07 curriculum standard to compare requirements of J07 domains with industry’s requirement. Relationship among J07 domains is clarified using importance weights and requirement levels. It is observed that the J07 domains should also focus on competences so that the graduates of the domain can achieve competency requirements.

We are currently executing the outcomes survey of ICT departments and graduates. 24 departments and 88 graduates have joined the survey. We are going to analyze (1) mismatch between industry’s requirement and achievement of ICT department, and (2) comparison of intension of ICT departments and perception of actual graduates. The analysis result of the achievement survey will be reported in the succeeding papers.

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References


