A Web-based Survey System to Analyze Outcomes and Requirements: A Case for College Level Education and Professional Development in ICT

Tetsuro Kakeshita and Mika Ohtsuki
Department of Information Science, Saga University, Japan
{kake,mika}@is.saga-u.ac.jp

Abstract

Various types of abilities such as knowledge, skill and competence are required to ICT (Information and Communication Technology) professionals. Systematic education system is required to develop such ability. In this paper, we propose a web-based survey system to analyze outcomes and requirements data for college level education and professional development. Although we are planning to use the survey system in the ICT domain, the system can also be used in other education domains. The outcomes and requirements data is collected using the common form representing BOK (body of knowledge) and competence under the same criteria to describe achievement and requirement levels of each survey area. Since the collected data is concrete, the survey system can provide quantitative information to analyze and evaluate many types of education systems and individuals. The system allows defining various types of attributes of each user and survey types to analyze the collected data from various viewpoints and to increase flexibility of the survey.

Keywords: Outcomes-based Assessment, Curriculum Development, Requirement Analysis, ICT Education

1. Introduction

Large number of professionals is required in ICT (Information and Communication Technology) domain, since information systems are recognized as an infrastructure of the society and almost every organizations. It is also recognized that the ICT professionals are one of the key factors to determine industry’s competitiveness.

Various types of abilities such as knowledge, skill and competence are required to ICT professionals. A systematic education system is thus necessary to develop such ability. College level ICT education and professional development activity such as initial and continuing professional development (IPD and CPD) at industry should cooperate to build a systematic education system.

However it is often said that there is a mismatch between outcomes of college graduates majored in ICT and industry’s requirement for ICT students. Although many efforts are performed both at academia and industry in order to develop ICT professionals, relationship among these activities is not clear.

The authors think that the main reason for this situation is that the vocabulary of each activity is different. As a result, industry does not understand the effort of the university, while the university does not understand the requirement of the industry. It is quite important and urgent to quantitatively analyze outcomes of education programs at various universities and requirements of various companies under the same terminology.

In this paper, we develop a web-based survey system to collect and analyze various outcomes and requirements data for college level education and professional development.

We have defined ICTBOK (ICT common body of knowledge) and classify knowledge and skill for ICT professionals [1]. ICTBOK is defined to cover a wide range of computing curriculum and various types of ICT jobs. The achievement or requirement level of each area is represented by an integer between 0 and 4 each of which corresponds to a rubric. These definitions enable to collect quantitative data on outcomes and requirements.

There is a large divergence among outcomes and requirements for individuals majored in ICT domain. For example, a student or an employee, a course and an education program have different types of outcomes. College level computing curricula is composed of five disciplines depending on the career of ICT graduates. The five disciplines are computer science (CS), information system (IS), computer engineering (CE), software engineering (SE) and information technology (IT). Requirements should be classified based on the types of target individuals such as CS graduates, qualified IT architect and project manager. The proposed survey system provides a wide range of flexibility to cover such divergence.

2. ICT Common Body of Knowledge

In order to evaluate an education program, it is essential to compare outcomes of and requirements for the program. We define ICTBOK to analyze outcomes and requirements for ICT professional development. Survey of outcomes and requirements are carried out
using the common form representing ICTBOK and a set of competence so that comparison among them becomes possible to analyze the survey data from various viewpoints.

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. The purpose of these skill standards is to clarify the skills needed for people working as various types of IT professionals in a systematic manner. We have analyzed the three skill standards and defined ICTBOK. ICTBOK also covers the teaching domain of college level ICT education by analyzing and integrating the five disciplines of Computing Curricula Standard J07 [6], which is clarified based on CC 2005 [5].

ICTBOK is composed of 6 categories, 22 fields and 143 areas. Although the areas are omitted due to space limitation, categories and the associated fields of ICTBOK are listed in the appendix.

3. Survey and Analysis Plan

The survey is carried out on the Web. ICTBOK and the set of competences are stored in MySQL database. A user (survey cooperator) first registers the system and enters his (or her) personal profile. The profile is represented by a set of attributes. Some of the attributes are common among all user types such as student, teacher and ICT engineer. Some attributes are defined depending on the user type. User types, attributes representing user’s profile, and attribute values entered by the users will be stored in the database. A user must login the system to protect personal information.

The system provides various types of surveys for each type of users. For example, a student may answer his outcomes when he gets into school and at the end of each academic year. A teacher may answer the outcomes of his course as well as the outcomes of the entire education program. The system collects a set of attributes for each survey. As in the case of the user profile, the attribute type may differ depending on the survey type. The related data is also stored in the database in order to provide flexibility of the survey plan.

A user enters the user profile and the survey attributes from web-based forms. On the other hand, the outcomes and requirements data are entered into the system using Excel worksheet generated by the system. There are two main reasons for this. The number of areas consisting of ICTBOK and the competence is relatively large so that data editing function is necessary for efficient data preparation. The editing facility such as cut, copy and auto filtering is a powerful tool for this purpose. Checking of the entered data and the protection mechanism of the cells are convenient means to maintain validity of the data. A user first downloads the Excel worksheet from the system and uploads the worksheet after preparing the outcomes or requirements data to enter the data into the system.

The following is a list of basic competences expected as a society member. They are developed by the ministry of economy, trade and industry of the Japanese government. We shall use these competences for the outcomes and requirements survey.

**Behavior**
- Ability to positively address things
- Ability to influence other people
- Ability to set a goal and to act towards the goal

**Thinking**
- Ability to analyze problem and find objective or cause
- Ability to plan a process and to prepare for the plan
- Ability of creation and/or invention

**Teamwork**
- Ability to explain one’s opinion
- Ability to listen to other people’s opinion
- Ability to understand different opinions or standpoints
- Ability to understand relationship between oneself and other people or matters
- Ability to keep social rules and one’s promise
- Ability to control stress

<table>
<thead>
<tr>
<th>Level</th>
<th>Knowledge</th>
<th>Skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Do not know</td>
<td>Cannot execute</td>
</tr>
<tr>
<td>1</td>
<td>Understand or know</td>
<td>Execute with detailed instruction</td>
</tr>
<tr>
<td>2</td>
<td>Explain</td>
<td>Execute with simple instruction</td>
</tr>
<tr>
<td>3</td>
<td>Join discussion using the knowledge</td>
<td>Execute with simple instruction</td>
</tr>
<tr>
<td>4</td>
<td>Utilize the knowledge for problem solving</td>
<td>Proficient in the skill</td>
</tr>
</tbody>
</table>

**Table 1: Achievement and Requirement Levels**

The user specifies the achievement or requirement level for each area of ICTBOK and competence. The level is defined as represented in Table 1 and provides a rubric of each area. The skill is taught in the case of level 1, while it is not taught in the case of level 0. Knowledge and skill levels are defined for each area of ICTBOK. But, only the skill levels are defined for each competence, since the knowledge of competence is considered to be common knowledge.

Systematic comparison among outcomes and requirements becomes possible by defining the levels.
using the same criteria. The knowledge and skill levels are defined considering our experience in accreditation activity for Japanese universities.

In the case of outcomes survey, each user will enter the data reflecting the actual achievement. However the requirements data may become unrealistic unless the user understands the actual achievement of the survey target such as student or IT engineer. The survey system thus supplies statistic distribution of the outcomes data corresponding to the requirements survey for the users before they upload the requirements data. The system also supplies various types of distribution of the survey data for the users after uploading the outcomes or requirements data so that they can examine the distribution to understand the level of their achievement and/or requirement.

4. Collection and Analysis of Outcomes

4.1. Collection of Outcomes

The outcomes data can be classified into three major categories: outcomes of a person, those of a course, and those of an education program. A person’s outcomes represent the ability of the person. Knowledge and skill of each area may be achieved by different ways, such as taking a course, OJT (On the Job Training) or previous school education etc. The outcomes of a course can be defined for each course or seminar. Instructor of the course can demonstrate the outcomes of his course with appropriate evidence. A collection of a course will construct an education program at an organization. The outcomes of an education program are a union of the outcomes of the courses and should be demonstrated by the organization. Usually such demonstration will be carried out through accreditation process in case of a university program.

Each category of outcomes survey corresponds to an independent survey type. It is necessary to collect different types of information depending on the category so that additional fields can be defined for each survey type. Some examples are listed below.

Outcomes of a person: Position or role (student, IT engineer, IT manager, etc.), academic background (Computer Science degree, non-ICT degree, etc.), job history, technical qualification

Outcomes of a course: Course type (required, optional, lecture, experiment, PBL), lecture hours, academic year

Outcomes of an education program: Type of educational organization (university, industry, etc.), discipline (CS, IS, IT, CE, SE, etc.), accreditation status, # of required credits

4.2. Analysis of Outcomes

Various types of analysis become possible by utilizing the outcomes data and the additional field data. A series of outcomes data of a single person represents a history of the person’s professional development. Checking of the personal history can be considered as a CPD activity. The difference between the outcomes of the beginning and the end of a period represents the achievement during the period. Such achievement will serve a measure to evaluate the person’s effort. Similarly the difference between the outcomes of a course or an education program represents the effect of continual improvement of the course or the program.

The distribution of the knowledge or skill levels for each area of ICTBOK or competence provides valuable information at various situations.

Consider the distribution of the outcomes of the students taking a course, a seminar or an education program. A student can check his outcomes level compared with other student’s outcomes. An instructor of a course can observe strong and weak points of his course by checking the distribution of student’s outcomes taking the course or the distribution of course outcomes teaching the same subject. This is the first step to design a course or to improve the course. Similar analysis is
possible for an education program. In this sense, checking of the outcomes is a powerful means for continuous improvement of an education program or a course. It is desirable to analyze outcomes distribution of education programs in order to develop realistic and useful curricula recommendation.

A company can analyze the knowledge, skill and competence distribution of their employees for effective human resource management. It is also possible for them to observe the distribution of outcomes of education program to find out appropriate organizations for recruiting.

5. Collection and Analysis of Requirements

5.1. Collection of Requirements

Compared with outcomes data, requirements data tend to be unrealistic unless appropriate restriction is imposed to complete the requirements worksheet. In this survey, we introduce the notion of weight of each area. A weight is an integer value which a user can add to each area of ICTBOK or competence in order to specify the degree of importance of the area. As a default, a user is asked to assign the weight 1 to 30 areas which the user considers important. However a user may assign an arbitrary integer value to each area in order to represent the degree of importance of the area. The survey system computes the sum of the weights added to all areas of the worksheet and normalizes sum of the weights so that all users are fairly treated.

The Excel worksheet for requirements survey is essentially the same as illustrated in Figure 1. The only difference is the additional weight column. Calculation of weight normalization is carried out when the worksheet is summarized.

As we have explained in the last paragraph of Section 3, the survey system provides distribution of outcomes to the users as a reference to prepare realistic requirements data. The survey system can provide various types of distribution data explained in Section 4.2. The types of supplied distribution data depend on the survey type. The system administrator can define the relationship between the survey type and the types of supplied distribution. The survey system works according to the defined relationship.

Like the categories of outcomes survey, there are various categories of requirements survey corresponding to the target such as high school or college graduates, graduate students, various roles and levels of ICT workers, and ICT qualifications. These categories are represented by the attributes of each survey. There is a variation of the requirements for the same target depending on the position, role and experience of the users. For example, a software development engineer often requires practical skills on software development or domain knowledge, while a manager typically requires knowledge and skill of higher abstraction level. Such attributes of each user is collected using user profile.

5.2. Analysis of Requirements

It is possible to analyze the requirements data from various viewpoints. The analysis which compares the requirements and the outcomes of the same target is useful to analyze mismatch between them. It is not always appropriate to completely eliminate the mismatch. But understanding of such mismatch is a first step of the fruitful discussion among stakeholders.

Comparison of a series of requirements can be a first step to design an education program or a skill development plan, since the difference between two consecutive requirements represents the effort expected to achieve the requirements at the end.

The sum of the weights added to each area can be used to evaluate importance of each area. The list of areas sorted by the sum of the associated weights can be a list of candidate areas for education or professional development. The weight of each area may depend on many factors. Some examples are the distinction of undergraduate or graduate program, intended role such as programmer, software architect or project manager. It is interesting to analyze the difference of the weight and the driving factors.

Distribution of the requirement levels of each area is useful to design the target achievement level of the area. We can define the satisfaction ratio of the area by the number of requirements whose levels are less than or equal to the achievement level divided by the number of all requirements. Like the case of weights, the distribution may be affected by many factors. Analysis of the distribution and the driving factors will be of interest.

6. System Design

The survey system maintains various types of data in MySQL database in order to provide flexibility. Figure 2 illustrates the Entity-Relationship diagram of the stored data. The blue entities, Field and Area, represent ICTBOK and the competence. The Level entity represents the rubric defined in Table 1. The red entities maintain profiles of each user. The User entity represents common attributes among all types of users while other entities represent specific user types. Among other entities, Survey Profile represents common attributes of all types of surveys. Four subtypes of the Survey Profile represent additional attributes depending on the survey type. The entities Outcomes and Requirements represent the data uploaded by corresponding Excel worksheets.
The survey system must represent various subtypes of User and Survey Profile to realize flexibility. The system should also represent various attributes of the subtypes. In order to satisfy these requirements, we design the database by defining two tables for each subtype. One table represents additional attributes of the subtype so that the table defines the data type and the default value of the attribute. It also defines whether the attribute value is required or optional. The other table represents the values of the optional attributes.

These functions are designed for general purpose survey of outcomes and requirements other than ICT education.

7. Related Work

Quality assurance of higher education is a global trend. Outcomes-based assessment is widely adopted among many accreditation organizations. IEA (International Engineering Alliance) and Seoul Accord define the notion of graduate attribute to describe the outcomes of the graduates of accredited education programs [3, 4].

In the field of computing education, joint task force of ACM (Association for Computing Machinery), AIS (Association for Information System) and IEEE-CS (Computer Society) developed a series of curricula recommendations [5]. Information Processing Society of Japan (IPSJ) announced the computing curriculum standard J07 [6]. Those curricula recommendations describe the standard or minimum outcomes of the graduates of an education program.

The activities of curricula recommendation and accreditation are closely related. In 2005, IPSJ made a research on average and minimum achievement levels at
28 departments majored in computing [7]. The research is on basic knowledge areas: algorithm, data structure, computer architecture, computer network, software design, programming language, programming, discrete mathematics and statistics. However, these areas cover only a small portion of ICTBOK.

We performed a small-scale survey on requirements for ICT graduate students [8]. 25 ICT professionals joined the survey. Variation among the requirements is large depending on number of factors such as position, role, and experience. Thus a larger scale survey is required to obtain reliable results. The survey system of the current paper mainly aims at a large scale survey of the outcomes and requirements in the field of ICT professional development and college level education. However the system can also be used for surveys in other education domains.

8. Conclusion

This paper mainly describes the purpose and design of the survey system. Quantitative analysis of outcomes and requirements is essential to develop an effective education system. The survey system provides functions for effective data collection and analysis. The system is flexibly designed so that it can be adapted to various types of surveys.

We are planning various types of outcomes and requirements survey which are described in this paper. The education committee of IPSJ decides to perform such survey as a follow up activity of J07. Result of the surveys will be reported in the succeeding papers.

Acknowledgement

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References


Appendix: Categories and Fields of ICTBOK

The following table describes the categories and the corresponding fields of ICTBOK. The number associated to each field is the number of areas corresponding to the field.

<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>Pure and 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>
</tr>
<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>Others</td>
<td>Additional fields or areas can be defined by the users, if necessary.</td>
</tr>
</tbody>
</table>