International Comparison of College-Level Computing Education

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***Abstract*—We have conducted a survey of computing education at Japanese universities in 2016. Purpose of the survey is to understand current status of college level computing education in order to develop reasonable computing curriculum standard considering international recognition. The questions were about program organization, enrolled students, teaching staff, computing environment, and other topics relating to organizing and operating computing education. For the purpose, we investigated computing education at 7 universities and 5 academic communities in USA, Australia and EU counties in this paper. We also compare the survey result and discuss the reason of the difference.**

Keywords—computing education, survey and analysis, international comparison, quality assurance in higher education

I. INTRODUCTION

Computing education is essential at many countries since IT is an important infrastructure at modern society and IT is strongly expected as a driver for business and/or social innovation. Information Processing Society of Japan (IPSJ) is developing a computing curriculum standard each 10 years for Japanese universities majored in computing and just published the new series of computing curriculum standard named J17 in March 2018.

We have conducted a survey of computing education at Japanese universities in 2016 [1][2]. Purpose of this survey is to understand various aspects of computing education at Japanese universities. We then surveyed college level computing education at US, Australia and EU countries by contacting various universities, accreditation bodies and government section. In this paper, we report the result of the international survey and compare the result with the survey at Japanese universities. The two survey projects are both important for the purpose to understand current status of global college level computing education in order to provide a knowledge basis for developing reasonable computing curriculum standard considering international recognition.

This paper is organized as follows. Related works are surveyed and compared with our work in Section II. We shall outline the survey questions and processes in Section III. Our survey of computing education at Japanese universities in 2016 is summarized in Sections IV. Our survey result of computing education in US, Australia and EU are explained and analyzed in Sections V to VII respectively.

II. RELATED WORK

International or nationwide comprehensive surveys on the status of some educational subject tend to be carried out regarding rather well-established subjects such as mathematics and science than relatively new subject as computing and informatics.

TIMSS (Trends in International Mathematics and Science Study) [3] was firstly executed in 1995, and is one of the representing international surveys aiming at evaluating educational outcomes on mathematics and science domain at elementary and secondary levels. The TIMSS survey contains inquiry into the status of pupils and students' achievement and national curriculums of mathematics and education as well. ACT National Curriculum Survey [4] is an example of the nationwide surveys which investigate curriculums of several subjects, such as English language arts, mathematics, science, that also appear to be well-established as educational subjects.

On the other hand, some examples of the surveys related to computing education are found, however their focus were mostly specialized on some limited aspects of education rather than entire picture of curriculum execution as we presented in this paper.

Goldweber et al. [5] reported how social issues of computing were included into computing curricula referring to an international survey of computing instructors. They investigate the social issues in higher educations' computing curricula, and provided a set of showcase practices to enhance the challenge of expanding the coverage of social issues in computing education. Simon et al. [6] presented an examination of the choice of the programming language in introductory programming courses based on parallel surveys conducted at Australian and the UK universities. They gave discussions on the possible reasons for the choice of the programming language based on the statistics obtained from the surveys. The discussions covered computing curriculum issues which appeared to affect the choice of the programming language. Comparative surveys focused on the curriculum contents were also found on computing education domain. For instance, Marshall [7] showed a comparison of the core aspects of the ACM/IEEE Computer Science Curriculum 2013 with the specified core of CC2001 and CS2008 to identify the changes of the curriculum. This kind of curriculum survey is in common with our survey in terms of their holistic viewpoints. However, the survey we conducted was about the 'actual execution' of the curricula in several universities placed at different countries, which gave unique nature to the survey we conducted.

Through the literature review, we came to find that our survey and comparative analysis have some specific features compared with the related works, and add original value to the survey. One of the most apparent features is the comprehensiveness. For instance, the questionnaire of the survey, as we see in the next section, contains both the questions about educational content and those about program overview as well. We have found another example of international survey on educational content concerning computing and informatics domain [8], however, its' focus was entirely on the 'educational content' aspect in our term. The survey which was done focusing on both the aspect of computing curriculum (which was covered by 'educational content') and that of educational environment and human engagement (which was covered by 'program overview') in one time is very unique among relevant surveys. Another aspect which made the survey original is its multi-angled nature. Our survey was conducted not only on computing departments but also on academic societies and accreditation bodies. This means that multi-angled views and opinions reflecting 'top view' (which had come from academic societies and accreditation bodies) and 'bottom view' (which had come from each of the universities) as well, which were especially about the execution of computing curriculums in higher educations, were compiled together on the results of the survey.

III. Survey Outline

We conducted a survey on the current status of computing education at computing and informatics major departments in United States, European countries and Australia. The survey consists of questionnaires and interviews.

A. Survey Questions

We made the questionnaire regarding computing education based on some reference materials, which will be explained in the following subsections.

The questionnaire consists of two parts, program overview and educational contents.

The program overview part is composed of general questions regarding program organization, student statistics, faculty members, educational computer systems and future plan at a department of the university. The questions are developed in common with the survey questions conducted in Japan in 2016 [1], so that we can recognize the feature of the survey outcome comparatively. The question items are listed below.

Name of University, Faculty, Department and Course

Program Organization

- Duration to graduation (year), study mode, degree type
- Accreditation status
- Relevant web pages
- Academic discipline of the program
- Corresponding computing domain defined in ACM/IEEE computing curricula series
- Required number of credits for graduation
- Lecture hour per credit
- Compulsory lecture, exercise, experiment, and graduation thesis
- Standard target academic grade for the computing education

Enrolled Students

- Number of Students
- Typical path of the students majored in informatics or computing discipline after graduation
- Difference of student career at IT and non-IT departments

Teaching Staff

- Number, belonging faculties, educational backgrounds, current major of faculty members
- Contribution of support staff and teaching assistant at computing programs

Computing Environment

- Presence or absence of educational computer systems (ECS)
- Student PC utilization
- Educational programing languages

Other Topics (If Any)

- Future plan to improve computing education.
- Relevant good practices in informatics education.
- Cooperation with IT qualifications/certifications
- Something specific to your country, university or department.
- Standards or guidelines used for computing and/or IT-related departments on their curriculum
- Status of computing education for non-IT departments
- Status of computing education at primary/secondary school

The educational contents part is prepared to collect information about teaching status of each content. Teaching status is defined as illustrated in Table I.

TABLE I. Teaching Status and Description

Teaching Status	Description
0	Have No Information
1	Seldom taught at computing programs (less than 25% of the students)
2	Sometimes taught at computing programs (between 25% and 50%)
3	Typically taught at computing programs (between 50% and 75%)
4	Usually taught at computing programs (more than 75%)
5	Required by accreditation criteria for computing program

The teaching content is defined by a common body of knowledge (BOK) represented in Table II. The BOK is defined based on the reference standard of informatics and additional topics related to general computing education [9]. The BOK contains 90 topics classified by 21 domains. Although the detail of the topics are omitted due to the space limitation, the BOK is used to precisely define educational contents of each program. While the entire BOK contains 90 topics, we developed the educational contents part using the domain level to reduce workload to respond to the survey questions. By providing a common definition of teaching status and BOK, mutual comparison will become possible across the national border.

TABLE II. ORGANIZATION OF COMMON BODY OF KNOWLEDGE (BOK)

Section	Domain	# of Topics
General Computing Education (GE)		9
(A) General Principles of Information		6
(B) Principles of Information Processing by Computers	1. Information Transformation and Transmission	4
	2. Information Representation, Accumulation and Management	4
	3. Information Recognition and Analysis	4
	4. Computation	6
	5. Algorithms	8
(C) Technologies for Constructing Computers that Process Information	1. Computer Hardware	3
	2. I/O Device	4
	3. Fundamental Software	3
(D) Understanding Humans and Societies that Process Information	1. Process and Mechanism for Information Creation and Transmission	2
	2. Human Characteristics and Social System	3
	3. Economic System and Information	2
	4. IT-based Culture	2
	5. Transition from Modern Society to Post Modern Society	2
(E) Technologies and Organizations for Constructing and Operating "Systems" that Process Information in Societies	1. Technics for Information System Development	7
	2. Technics for Information System Utilization	6
	3. Social System Related to Information	2
	4. Principle and Design Methodology for HCI	4
(F) Competence	1. Professional Competency for IT Students	3
	2. Generic Skill for IT Students	6

B. Survey Process

The questionnaire and interviews are carried out during January and February in 2018. After preparing the survey questionnaire, we firstly selected the candidate universities having computing department. We did it in terms of university ranking referring to the Times Higher Education World University Rankings because we hoped to investigate into both top-level and middle-level universities for each region. Then we narrowed down the candidate university list to several universities per regions (US, UK, other European countries, and Australia) concerning the availability of the contact person to whom we ask for a permission of the investigation. Then we asked for the permission to the contact persons of the listed universities and sent the questionnaire by email if the permission was given. We obtained the answer of the questionnaire from 7 universities (3 from US, 3 from UK, and 1 from Switzerland). And we visited some of the universities (1 US university, 3 UK universities, and 1 Switzerland university) and conducted interview investigations.

We also selected representative academic community working on computing curriculum standard development, computing accreditation or promotion of collaboration among universities for quality assurance of computing education at each country. Although we cannot investigate all the universities, we expect to understand the entire picture of the computing education at each country by asking such academic community.

IV. COMPUTING EDUCATION AT JAPANESE UNIVERSITIES

There are four types of college level computing education in Japan (and possibly in other countries).

A) Computing education at a department or a course majored in computing discipline

B) Computing education at a non-IT department or a course as a part of their major field of study

C) General computing education for all university students typically at the first or second academic year

D) Computing education to obtain high school teacher license on computing subjects

We conducted a national survey of Japanese universities on computing education in 2016 [1][2]. The survey is composed of five survey types A through D described above as well as the survey type E for educational computer system.

Our survey was the first national survey on computing education at Japanese universities, since there was no widely accepted definition of computing education. We recognize that such situation is essentially the same at other countries.

However the situation has changed. The Science Council of Japan developed the reference standard of informatics [10] for university education in March 2016. The reference standard provides a common BOK for college level computing education, which covers the five domains defined in CC2005 [11], namely Computer Science (CS), Computer Engineering (CE), Software Engineering (SE), Information Systems (IS) and Information Technology (IT). The Japanese Ministry of Education (MEXT) accepted this as a definition of computing education. Thus we can use the reference standard as the definition of computing education for our survey.

Among the five survey types described above, the survey type A is closely related to this paper. The survey covers various aspects including program organization, quality and quantity of educational achievement, students, teaching staff and computing environment. These survey questions are prepared by considering the Japanese standards for establishment of universities and our accreditation experience of computing programs in Japan.

The estimated number of computing departments and students is about 300 and 28,000 respectively. 50% of the students belong to engineering faculties. Although 25% of the students are learning computer science, 50% of the students are learning computing domains other than those defined in CC2005.

As shown above, CC2005 defines the five computing domains. However the corresponding BOKs are different depending on the domain so that mutual comparison is impossible across different domains. We utilize the common BOK to enable mutual comparison of the responded programs.

We utilize the web-based survey since we did not exactly know the actual organization for the survey in advance. After preparing various documents such as user manual and detailed instruction of the survey questions, we sent the formal request letter to all universities in Japan with a reference letter from the Japanese Ministry of Education in order to increase the response rate.

We collected 279 answers as a result of the survey. Each answer is provided either by a faculty, department or course so that the number of computing departments does not directly correspond to the number of answers. We examined the answers to have Table III representing the number of universities, faculties and departments having computing department or course.

TABLE III. NUMBER OF COMPUTING DEPARTMENTS IN JAPAN

	University	Faculty	Department
National	53	61	75
Public	22	22	29
Private	108	133	163
Total	183	216	267

We estimate that the response rate is approximately 85% for this survey. The response rate is quite high considering that each organization must independently register to the web-system. This becomes possible because of the strong support of the Ministry of Education, Japan.

TABLE IV. STUDENT'S CAREER SELECTION AFTER GRADUATION IN JAPAN

Career Selection	National	Public	Private	Total
Graduate School (Computing)	2,620	388	1,309	4,317
Graduate School (Other)	338	57	237	632
Hired at Company, Gov. etc.	2,409	1,093	12,198	15,700
Others (incl. unknown)	231	52	1,828	2,111

Table IV represents the computing student's career selection after graduation in Japan. It should be noted career selection is completely different at national, public and private universities mainly because that tuition fee of typical private university is significantly higher than that of a national university in Japan. Many of the national university graduates are willing to study at a graduate school because they can expect higher salary if they have a Master's degree.

V. COMPUTING EDUCATION AT US UNIVERSITIES

Computing education at US universities are investigated by a questionnaire and interview to the independent departments, accreditation organization and curriculum development body. The information obtained from the curriculum development body and accreditation organization is useful to understand overall situation of the computing education in US, while each department provides specific information at the department.

A. Computing Curriculum Development

CC2005 has been utilized to overview the entire organization of the specific computing curriculum of five domains: computer science (CS), computer engineering (CE), software engineering (SE), information systems (IS) and information technology (IT).

However, after 10 years of the CC2005 publication, domain of the computing discipline is expanding. ACM and IEEE-CS are developing curriculum standards for two more domains: cyber security (CSEC 2017) and data science.

CSEC 2017 is composed of 8 knowledge areas (KA) and crosscutting concepts across KA's. The 8 KA's are data security, software security, component security, connectivity security, system security, individual security, organizational security and societal security.

On the other hand, there are at least three types of existing data science programs: database (DB), artificial intelligence (AI), and statistics or applied mathematics. Although the data science curriculum standard based on applied math is already published, data science curriculum based on computing discipline is still under discussion. This is mainly because that the principles of DB and AI are largely different. One possible solution to resolve the discussion will be to investigate job descriptions and required abilities appeared in various job advertisement. Curriculum development based on such investigation will be useful to both of academia and industry.

Currently each of the curriculum standards uses different terminology depending on each domain. Thus it is difficult to understand relationship among different domains. ACM and IEEE-CS launched the CC2020 project in order to overview the entire vision of the computing curriculum standards and to clarify relationship among them.

B. Computing Accreditation

ABET/CAC (Computing Accreditation Commission, Accreditation Board for Engineering and Technology) provides computing accreditation in US. Since there is no mandatory accreditation for US universities imposed by law, ABET accreditation is widely utilized to ensure quality of education in US. This is a difference from Japan where there is a national regulation of mandatory accreditation.

ABET typically defines their accreditation criteria considering their experience of accreditation visit and tries to avoid recommendation to a specific item. This means that there is basically no collaboration between accreditation body and curriculum development organization. Such situation is different from Japan, where computing curriculum standard is often referred during accreditation examination in order to justify a computing program.

However, the situation in US is changing. ABET recently announced accreditation criteria for cyber security program at the end of 2017. The criteria are developed based on CSEC

2017 so that collaboration between accreditation and curriculum development is at a preliminary phase.

C. Computing Education at Independent Department

We investigated three computing departments in US. Department A belongs to a top-level university without ABET accreditation. Department B is preparing to be accredited by ABET. Department C is a typical computing department accredited by ABET. These departments provide CS, CE and IT programs. All the programs reference ACM/IEEE-CS computing curricula at their specialized domain.

Fig. 1 illustrates expected learning rates of these programs at each domain defined in Table II. GE, (B)-2, (C)-3, (F)-1 and (F)-2 are commonly taught at all programs with high learning ratio so that they can be regarded as common topics for computing education. We observe that expected learning ratio at non-accredited program tends to be low since each student has more flexibility of selecting subject.

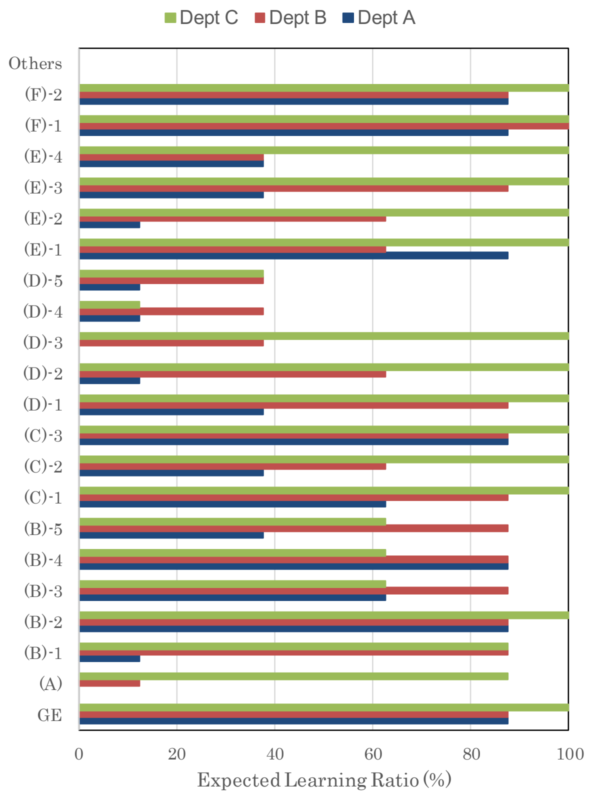

Fig. 1. Expected Learning Ratio of the Examined Programs in US

The number of students is rapidly increasing at department A in these ten years. This is because that IT engineers are becoming highly evaluated from industry and at the society.

We compared advertisement offering employment of a software engineer in US and Japan. Required ability and job description, i.e. authorized power and responsibility are clearly described in an advertisement in US. Such information is comparatively unclear in Japan. This is because a Japanese software engineer is not employed as a specialist and is expected to do a wide range of tasks defined in a process standard such as ISO/IEC 12207 [12].

There is a survey research [13] showing that productivity and confidence of IT engineer is significantly higher in US compared to other countries. On the other hand, productivity and confidence of IT engineer is significantly low in Japan primary. Partial reason is that the working time is longer and low hourly salary is lower than other countries. More fundamental reason is the difference of the degree of risk taking at business management and mobility of software engineers across companies and countries. This also results in that most of the graduates are employed and do not go to graduate school at this department in US.

Although the number of students is rapidly increasing at department A, the increase of the number of faculty members is much slower. This causes an overload problem of the faculty members so that the department employs many teaching assistants. There is a potential risk of degrading quality of education. Such type of problem is unlikely to happen in Japan, although the student teacher ratio is typically higher at private universities than at national/public universities. This is because that the Japanese standards for establishment of universities impose a certain number of faculty members to the university according to the number of students in Japan.

We also find that most of the faculty members at the departments A, B and C graduated departments majored in computing discipline. The situation is quite different from that in Japan where it is often observed that majority of the faculty members of the computing department graduated non-computing departments. This is because the number of computing departments is rapidly increasing in Japan so that many universities must hire Ph.D. holders graduated an engineering or science departments as faculty members.

VI. Computing Education at Australian Universities

We conducted a survey questionnaire and interview to a representative of ACS (Australian Computer Society) in charge of computing accreditation provided by ACS. ACS is also in charge of defining accreditation criteria and certification for professionals so that we can expect that they have much information about current status of computing education in Australia.

A. Overview

No formal survey has been carried out on computing education at Australian university. Currently ACS has accredited 124 departments at undergraduate level and 70 graduate schools at graduate level. Among the 124 accredited departments, 58 are majored only in computing discipline, 22 are joint program with business, 14 are engineering programs and 21 are science programs. It is expected that the number of computing students are 50,000 for each academic year. The total number of faculty members teaching computing is estimated about 1,000.

Computing education in Australia typically does not correspond to ACM/IEEE-CS curriculum standard. Each department rather references ACS Core Body of Knowledge for ICT Professionals (CBOK) developed by ACS since ACS is a representative computing accreditation body in Australia. Fig. 2 represents expected learning ratio based on CBOK. Since CBOK covers a limited set of topics of our common BOK, the learning ratio of other topics tend to be low because of the variety of programs.

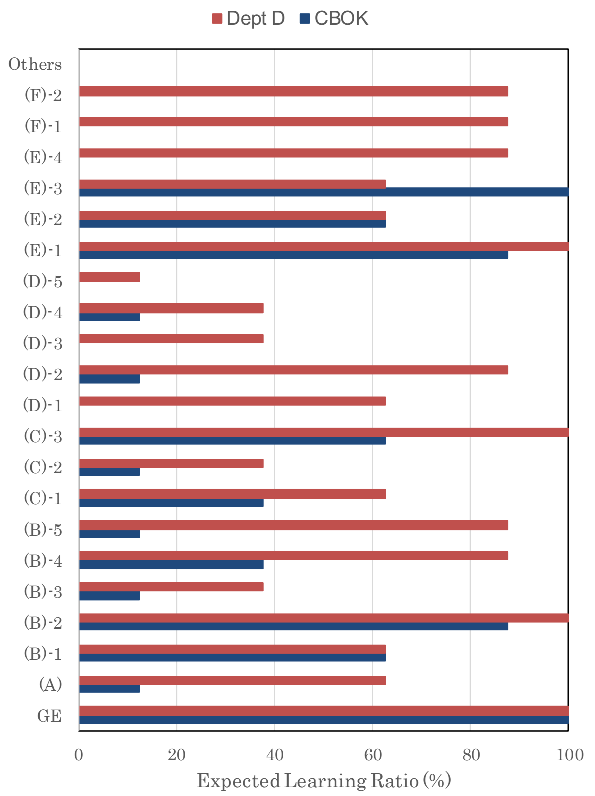

Fig. 2. Expected Learning Ratio of CBOK and Department D

B. *Computing Accreditation and Related Topics*

As mentioned before, ACS is a representative computing accreditation body in Australia. ACS also is a principal member of the Seoul Accord, which is an international agreement of accreditation in the computing domain.

ACS also provides a certification named ACS Certified Professional/Technologist and is developing a framework for mutual recognition of certifications for IT professionals through IFIP IP3 (International Federation of Information Processing, International Professional Practice Partnership).

Unlike the case of ACM and IEEE-CS, ACS itself does not provide computing curriculum standard. Instead ACS defines CBOK to establish collaboration of accreditation and certification. CBOK is composed of essential core ICT knowledge (ICT professional knowledge and ICT problem solving) and general ICT knowledge (technology resources, technology building and ICT management).

Deep understanding of essential core ICT knowledge in CBOK is required to seek ACS accreditation. On the other hand, a student is required to understand the concepts of general ICT knowledge at least conceptually. Each computing program must first provide a mapping between their teaching contents and CBOK and then present Bloom's achievement level of each topic during the accreditation process. Such a mapping enables clarification of the teaching contents in terms of CBOK.

However, ACS does not define specific requirements about student's skill. Instead they define requirements to the capstone project. A capstone project is a special project to develop skill and competency to the students. At least 25% of the effort of a semester must be assigned to the capstone project. Various types of evaluation modes are permitted to evaluate students at a capstone project. Some examples are student report, graduation thesis and project evaluation.

CBOK is also utilized to define requirements of ACS certification and is referenced from major frameworks such as Australian Qualification Framework (AQF), Skill Framework for the Information Age (SFIA) and Seoul Accord. This means that CBOK provides a common terminology throughout the development of various frameworks.

VII. Computing Education at European Universities

A survey of European universities suggests that there is room for a partially joint curriculum, given the perceived need to be able to compare, even partially, the curriculum of the UK, say, with that of Italy. A lack of communication results in the same concept being expressed in different words, and in the same words being used to express different concepts. If this is not rectified, it will surely have an impact on the careers of IT professionals in the global marketplace.

A. *Overview*

The Bologna Process, signed by education ministers from 29 European countries in 1999, was intended to ensure a comparable standard of higher education throughout Europe. They currently have 48 member countries.

The EU government does not have statistics on computing education at European universities. Instead they introduced us a representative of Informatics Europe to accept our visit and hearing.

Informatics Europe recognizes and respects national differences in the way informatics is interpreted and implemented throughout Europe. According to President Enrico Nardelli, these arise because of the different contexts and education systems that exist in each European country, and the organization's stance is that each country should be responsible for developing its own curriculum. The sheer number of languages across the continent would also make the implementation of a single unified curriculum difficult. However, Professor Nardelli suggests that most European universities' informatics curricula are likely to be based on the ACM curriculum, since no other equivalent standard exists in Europe. For example, he described the Italian curriculum as referencing approximately 40 topics from the ACM curriculum.

B. *Computing Education Reported by the UK Academic Organizations*

In order to overview a wide range of topics covered by the computing discipline, the UK's Quality Assurance Agency for Higher Education (QAA) has established Subject Benchmark Statements (SBS) for Computing education at the undergraduate [14] and Master's [15] levels. The SBSs also provide an idea of expected levels of achievement for students studying the subject. They do not constitute a national curriculum, but are intended to assist with program design, delivery and review, allowing for innovation and flexibility within an overall conceptual framework [16]. The QAA referred to the ACM curriculum in establishing the SBSs.

Another UK institution with an interest in computing standards at university level is the British Computing Society (BCS), part of whose mission is "to develop and maintain standards in educational qualifications that provide an appropriate foundation for those who wish to follow a career in computing or information systems." One way in which it accomplishes this is by accrediting computing programs. Graduation of an accredited program is a prerequisite to fulfil the requirements of the BCS's own Chartered qualification, entitled "Chartered IT Professional"(CITP), which are mainly in the broad area of computing/computer science, with specializations including (but not restricted to) areas such as information/cyber security, networks and databases, games programming, information systems, big data, internet of things, web development, software engineering, user experience design, artificial intelligence, and robotics.

According to the UK's Higher Education Statistics Agency [17], there were 101,145 students studying computer science in higher education in the UK in 2016/17 (of which 81,215 were UK students, 8,315 were from the EU, and 11,610 were from outside the EU). Around 70% of graduates proceed to the workplace, while approximately 20% go on to further study.

C. *Computing Education at UK University*

Department D in the UK has a large informatics department with 300 first year students and 45 teaching staff. Given the size of the department, it makes full use of support staff and teaching assistants, with approximately 1 TA per 20 students.

The expected learning ratio of department D is illustrated in Fig. 2 in the previous page. The department is accredited by BCS, which demands a rigorous core curriculum; this could account for the high percentage of students taking subjects across the common BOK.

A high percentage of students taking a course has been taken as evidence of the importance the university places on that course. Likewise, in our common BOK, many topics are assigned high priorities. A comparison of UK and Japan shows, unsurprisingly, that general computing education along with algorithms, are widely studied in both countries.

Areas of significant difference also appear to exist, however. For example, there appears to be a difference in the significance placed on "computer hardware", and even more so on "fundamental software", with the later a prerequisite for accreditation at the UK University, whereas the number of subjects offered in Japan is low. Likewise, "human characteristics and social systems" appear to be more highly weighted in the UK, as do "professional competencies for IT students."

It must be remembered, however, that whereas the Japanese data is representative of universities across the country, the sample from the UK represents one university only, and a lack of standardized national curriculum means that results are likely to vary from university to university.

Department E belongs to one of the top-level universities in UK and focuses on the basics of IT in the first year in order to ensure that all students are at the same level. First year studies fall into three main categories: programming, hardware, theory (including basic theory as well as applications of computing such as AI), and mathematics. The most important requirement for the first year students are the ability to use multiple programming languages (e.g. Java, ML, Python, SQL), algorithm analysis, and discreet mathematics. The first year course also includes a 20% practical component.

At the second academic year, students may study one of the three courses made up of 75% computer science and 25% mathematics (CST75), or 50% computer science, 25% mathematics and 25% natural or behavioral sciences (CST50). In the second year, students study programming, hardware, theory, and applications (including AI, graphics, and software development), and by the end of the year will have covered all content recommended by ACM, IEEE, and BCS. CST75 students will also have studied additional topics such as economics, law and ethics, concepts in programming languages, and formal models of language. 20% of students' final mark for the second year consists of a group project. Groups of six or seven students work together to solve a problem posed by a corporate "client", for whom they act as consultants.

For the students in the third academic year, all subjects are optional. Their final exam paper consists of three papers of 15 questions each, of which they must answer five each. The timetable is structured in such a way as to allow students to take all courses should they so wish. This implies a high level of motivation. Third year courses include bioinformatics, digital signal and natural language processing, comparative architectures, machine learning and Bayesian inference, as well as more in-depth study of topics already covered in earlier years such as algorithms, graphics, and security. Third years also complete a dissertation, which they write over the course of the year.

As a reader can observe from the above explanation, the computing education at department E is rather special as in the case of Department A mentioned in Section V. We consider that an education to develop top-level students, expected as innovation driver, need to focus on some topic in order to extend strength of each student rather than covering a wide range of computing topics.

D. *Computing Education in Switzerland*

Swiss universities are also responsible for setting their own curricula, as in the case of one Swiss university, which renewed its informatics curriculum two years ago. The university referenced the ACM curriculum when renewing its curriculum; however, it tailored the curriculum to suit its own needs, replacing hardware topics with studies in economics and business administration.

VIII. CONCLUSION

We investigate the current status of computing education at universities in US, Australia and EU countries in this paper. We also compare the status with that of computing education in Japanese universities. Although the number of investigated departments is not many, we compensate this through questionnaire and interview to academic society in computing domain.

The number of the sample of the universities in this study is very small mainly because of the limitation of the resources we could use for the study. We recognize the reported investigation in this paper as a pilot case to prepare for further studies. Web based inquiries, we think for instance, which cover broader regions and universities will complement the limitation. We expect that our case will be a trigger of the emergence of further studies relating to the global comparative research into computing education.

We found differences in many aspects in education system, education contents and social situation among the countries. However, some of the good practices can be shared by many countries. Such practices include: Developing common BOK to define computing discipline; collaboration of organizations such as education program, curriculum standard development, computing accreditation and certification; Mutual mapping of education contents across the national border and computing domains. Such effort will be quite beneficial to increase the degree of quality assurance in computing education and to raise social position of the IT professionals which computing students will be expected to be.

Taking the research result on the Japanese case of computing education as a comparison case, this study attempted to show a comparative view on the current status of global computing education. The importance of computing education is common among the global society, and the Japanese case will be an instance to understand comparatively an aspect of the current status of global computing education. It should be noted that, as far as we investigated, the comprehensive study into the current status of computing education hasn't done in other countries or regions other than Japan.

Additionally, this study is unique in its use of the comprehensive view given by the BOK based on the reference standard of informatics for making survey questionnaire. Through this study, we re-recognized the indispensability of such comprehensive view showing mutual relationships among each domain, such as CS, CE, SE, IS, and IT, of the computing education.

For the future topic, we are willing to support other countries or organizations to execute detailed survey project on computing education like our survey at Japanese universities. Many discoveries will be expected to improve computing education by analyzing information collected through such survey projects.

ACKNOWLEDGMENTS

We appreciate the faculty members and staff who took their time to respond to our survey. This work is supported by the Japanese Ministry of Education and JSPS Kakenhi Grant Number 16K01022.

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