A Comparison Analysis between Achievement and Requirements for Computing Education

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***Abstract*—We have conducted a national survey of computing education at Japanese universities in 2016. We then developed computing curriculum standard J17 for the departments majored in computing. In this paper, we perform a comparison analysis between achievement and requirements for computing program. We collect requirements for computing programs through a survey at five J17 curriculum development committees: CS, CE, SE, IS and IT. We also compare the achievement of existing computing programs and the requirements of the committees using the proposed framework. Reasons of the differences are analyzed also in this paper. Furthermore, we find many computing programs which do not correspond to neither of the requirements. Although the analysis is performed under the context of Japan, it can also be applied to computing education at other countries.**

Keywords—achievement analysis, requirement analysis, comparison analysis, computing education, educational survey

I. INTRODUCTION

Computing education is essential at many countries since IT (or ICT) is regarded as an infrastructure of the modern society and also expected as a driver for social and/or business innovation. However the current status of computing education is not widely recognized since the definition of computing education is not clear at many countries. We have conducted a national survey on computing education at Japanese universities in 2016 [1][2]. We utilized the reference standard of informatics [3] in order to define college level computing education in this survey.

The above survey is supported by the Japanese ministry of education (MEXT) so that many of the Japanese universities responded to the survey questions. Through the survey, we collected the educational contents and achievement levels at each topic from each of the educational programs. The topics are selected based on the reference standard of informatics. The survey result was utilized when Information Processing Society of Japan (IPSJ) developed their computing curriculum standard named J17.

In this paper, we shall compare achievement and requirements for computing programs. We collect the requirement data to the college level educational programs from the viewpoints of J17 computing curriculum committees developing body of knowledge (BOK) at each computing domain, i.e. Computer Science (CS), Computer Engineering (CE), Software Engineering (SE), Information Systems (IS) and Information Technology (IT). We also compare the achievement data at each program collected in 2016 and the requirement data using the proposed framework. Such comparison is quite important in order to minimize the recognition gap between the intension of the curriculum development committee and understanding of each educational programs.

In Section II, we shall explain the background of this work and introduce related works. We shall also discuss difference between our contribution and the related works. In Section III, we shall introduce the outline of the survey in 2016. The collection of the requirement data is explained in Section IV. In Section V, we define the notion of coverage by comparing the achievement of an educational program and a requirement of a computing domain. Mutual comparison between the requirements and the achievement are discussed in Section VI for each computing domain. We also find many computing programs which do not correspond to single computing domain so that we shall discuss this issue in Section VII.

II. RELATED WORK

ACM and IEEE Computer Society (IEEE-CS) have developed computing curricula series including CS, CE, SE, IS and IT [4]. Recently CSEC 2017 was released in the field of cybersecurity in February 2018. These curriculum standards define independent body of knowledge (BOK) for their curriculum since they are developed by separate academic communities. As a result, relationship among these curriculum standards becomes unclear.

It is not desirable that the relationship among various computing curriculum standards is unclear, since many of the students majored in computing discipline are expected to contribute to the society as IT professionals. It is expected that there is a common set of terminologies among IT professionals. It is also important to provide common BOK such that the society can recognize difference among various computing domains such as CS. It is also expected that computing department and accreditation body utilize the same terminology.

Considering the above situation, there are many projects to develop common BOK to understand difference computing domains. Although many of such projects have been conducted from the viewpoint of industry and government, few has been conducted from the viewpoint of academia.

IEEE-CS is developing EITBOK [5] for enterprise IT services. Australian Computing Society (ACS) developed CBOK [6] as a common BOK for IT professionals and utilize CBOK for college level computing accreditation and IT certification. European Commission is currently developing fundamental ICT-BOK [7] in order to define required knowledge for IT professionals. ISO/IEC JTC1/ SC7/WG20 is developing ISO/IEC 24773 [8] and demonstrates the importance of mutual relationship among various BOKs and competence frameworks for IT professionals. The reference standard of informatics [3] developed by Science Council of Japan is one of such project from the viewpoint of academia. In 2017, Accreditation Board for Engineering and Technology (ABET) seeks feedback on proposed accreditation criteria for cyber security programs based on CSEC 2017. Collaboration of computing curriculum development and computing accreditation is just beginning in US.

Since the development of common BOK and the utilization of the BOK are at the initial stage at academic sector of many countries, we can only find few related works in IS domain.

There are some works [9]-[11] to investigate teaching topics at undergraduate IS education programs in terms of ACM/AIS IS 2010 [12] learning units. IS programs are identified based on public information on university web sites so that the identified programs may cover other computing areas. In these works, program data was obtained from the university web sites such as syllabus and these works did not address the concept of achievement level. On the other hand, we shall define the achievement levels considering Bloom's taxonomy and introduce the notion of coverage to develop comparison framework between requirement of a specific domain and achievement of a specific education program. We also define common BOK to understand relationship between difference computing domains.

III. National Survey on Computing Education at Japanese University

There are four types of college level computing education in Japan (and possibly similar 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]. 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 [3] for university education in March 2016. The reference standard provides a common body of knowledge (BOK) for college level computing education. 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.

Table I represents the six achievement levels for knowledge and skill defined for the survey of quality and quantity of educational achievement. These levels are used to define quality of education.

TABLE I. Knowledge and Skill Level Definition

Level	Knowledge Level Definition	Skill Level Definition
0	Not taught (unnecessary or already taught)	
1	Not taught because of the time limitation or because the level of the contents is too high	Taught at class with simple exercise
2	Taught at class. Students know each item.	Taught at class with some exercise. Students can perform the topic if detailed instruction is provided.
3	Taught at class. Students can explain the meaning of each item.	Taught at experiment with more complex exercise. Students can perform the topic with simplified instruction
4	Taught at class. Students can explain relationship and/or difference among related terms.	Students perform combined research project containing the topics so that the students can autonomously perform the topic.
5	Taught at class or graduation research project. Students can teach related domain or subject of the terms to the others.	Students perform combined research theme containing the topic. Students can teach how to perform the topic to the others.

We also define a common BOK based on the reference standard of informatics and additional topics related to general computing education [13]. The BOK contains 90 topics classified by 21 domains as represented in Table II. 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.

CC2005 [4] defines five computing domains: CS, CE, SE, IS and IT. 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.

TABLE II. ORGANIZATION OF THE 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

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 97 answers as a result of the quality survey of educational achievement. 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. Although the number of collected answers is smaller than the number of responses (279) to the survey, it is larger than 75 which is the estimated number of samples calculated under the assumption of universe size 300 and 10% statistical error. Therefore our discussion is statistically reasonable.

IV. REQUIREMENT ANALYSIS OF COMPUTING DOMAINS

Considering the structure of CC2005 [4] proposed by ACM, AIS and IEEE Computer Society, IPSJ developed our new curriculum standards J17 in five domains: CS, CE, SE, IS and IT. We asked the following questions to the five curriculum committees developing BOK of each domain. Then we can collect requirements of each domain in a uniform manner.

1. Whether each topic of the common BOK is core or elective of the domain.
2. Expected minimum achievement level for each topic as a core and an elective knowledge and skill.
3. Expected enrollment ratio for the elective topics

Table III represents the answer of the J17-IS curriculum development committee for the questions 1 and 2 defined above. Other committees also provided their answers in the same format. The table summarizes the requirements for each domain of the common BOK. The blank columns means that the committee requires nothing for the combination of the corresponding domain and the knowledge/skill category. If the committee answers different levels to the topics at the same domain, the minimum and the maximum values are represented like 2-3.

TABLE III. EXAMPLE OF REQUIRED LEVELS (INFORMATION SYSTEMS)

Section and Domain	Knowledge		Skill	
	(Core)	(Elective)	(Core)	(Elective)
GE				
(A)				
(B)-1				
(B)-2	2-3	4	3	4
(B)-3	2			
(B)-4				
(B)-5				
(C)-1				
(C)-2				
(C)-3	3		2	
(D)-1	2	3		
(D)-2	2	3		
(D)-3	2	3		
(D)-4				
(D)-5				
(E)-1	2	3		2-3
(E)-2	2	3		2
(E)-3	2	3		
(E)-4	2	3		2
(F)-1	3		3	2-3
(F)-2				

J17-IS requires relatively high levels of knowledge and skill for the following domains and sections. They are the important topics from the viewpoint of J17-IS.

- Domains (B)-2 and (F)-1
- Sections (D) and (E)

Knowledge and skill requirement levels are mostly in the range of 2-3 for these domains and sections. The readers may recognize from Table I that such levels are not high. This is because that J17-IS covers computing education at lecture, exercise and experiment and does not contain education through graduation thesis project typically done at the fourth academic year at many universities in Japan.

There are several domains in Table III that all of the required levels at four knowledge/skill categories are blanks. The J17-IS committee expects that the topics in these domains are taught at introductory computing courses and their knowledge requirement levels are 1.

V. Classification of Computing Programs using Requirement Data

We shall define the notion of coverage of an education program *P* for a particular computing domain *D* in this section. Our comparison framework is developed based on the four types of coverage values. Let $Lv(P_i)$ be the achievement level of *P* for the *i*-th topic of the common BOK defined in Table II.

The coverage values are computed for the following four cases so that we shall define the coverage for these cases.

1. Coverage of knowledge for core topics
2. Coverage of knowledge for elective topics
3. Coverage of skill for core topics
4. Coverage of skill for elective topics

We shall independently define the four coverage values since knowledge and skill are the different concepts and weight of core and elective topics are different depending on computing curriculum standard. The overall coverage is the minimum value of the coverage values for the above four cases so that it is possible represent the coverage by a single value.

Let $Lv(D_i)$ be the requirement level of *D* for the *i*-th topic of the common BOK. Then the coverage of the program *P* for domain *D* is defined by the following formula for the required subject.

$$\frac{\sum_i \min(Lv(P_i), Lv(D_i))}{\sum_i Lv(D_i)}$$

This formula implies that the coverage value is not affected even if the achievement level of the program P exceeds the requirement level of the domain D. It also implies that the topics with higher requirement levels affect the coverage value.

The coverage value for the optional subject is defined below. This is a modified version of the above definition considering the expected enrollment ratio *E* supplied by the curriculum development committee of the domain.

$$\frac{\sum_i \min(Lv(P_i), Lv(D_i))}{E \times \sum_i Lv(D_i)}$$

We observe that the four coverage values of an education program *P* varies depending on the program. Thus we define that a program *P* conforms to a domain *D* if each of the four coverage values of *P* for *D* exceeds a predefined threshold value. We selected 90% as the threshold value in this paper. This implies that a program can be conformed to multiple domains.

VI. Analysis of Classified Computing Programs

We shall analyze the classified computing programs in this section. The classification is based on the conformance defined in the previous section.

A. Computer Science (CS)

31 programs conform to computer science domain. Table IV represents the number of programs which conform to each of the five computing domains as well as the statistics of the response from the 31 programs about their perception of the matching domain. It should be note that a program can conform to more than one computing domains, although each program selects only one perceived domain. Thus the total number of perceived programs is equal to the number of programs conformed to CS.

TABLE IV. Number of Conformed Programs and Perception of the CS Recognized Programs

	CS	CE	SE	IS	IT	Others	Total
Conformed	31	27	22	25	30	-	-
Perceived	10	2	0	4	5	10	31

As can be observed from Table IV, there is a big difference between the conformed domains and the perceived domain of each program. Currently the requirement of each computing domain is not described precisely so that education programs cannot clearly understand the intension of the curriculum standard of the intended domain. Our comparison framework will be useful for curriculum development at each education program.

We can observe that the number of programs conforming to IT (30) is almost equal to the number of programs conforming to CS (31) in Table IV. This implies that the class of programs conforming to CS is similar to a subclass of programs conforming to IT. In other words, the CS requirements are strictly stronger than the IT requirements. Such comparison is useful to clarify relationship among different computing domains.

In case of the J17-CS curriculum standard, sums of the required levels are 80 for core knowledge, 81 for elective knowledge, 85 for core skill and 87 for elective skill. It is rather difficult for an education program to conform to CS requirements particularly for the elective topics, since the expected enrollment rate for the elective topics are 80%, which is higher than the rate of other domains. Fig. 1 represents the distribution of the number of programs at each coverage value.

Although many of the coverage values exceeds 95%, we frequently observe education program which has a coverage value less than 90%. That is the reason that the number of programs is not many whose overall coverage value exceeds 90%.

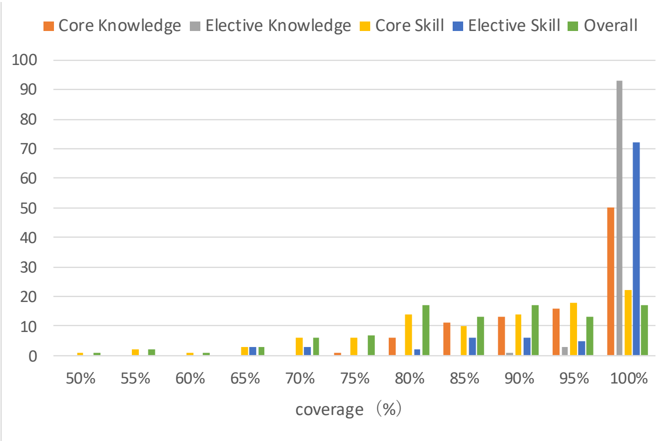

Fig. 1. Distribution of the Number of Programs for Each Coverage Value for Computer Science

B. Computer Engineering (CE)

We found 49 programs conforming to CE. As the readers can observe from Table V, there is a big difference between the conformed domain and the perceived domain of each program as in the case of CS. The number of conformed CE programs at each domain other than CE is significantly smaller than the number of programs conforming to CE. Thus we can conclude that CE requirement is different from the requirements of other computing domains.

TABLE V. NUMBER OF CONFORMED PROGRAMS AND PERCEPTION OF THE CE RECOGNIZED PROGRAMS

	CS	CE	SE	IS	IT	Others	Total
Conformed	27	49	20	28	33	-	-
Perceived	19	5	0	5	6	14	49

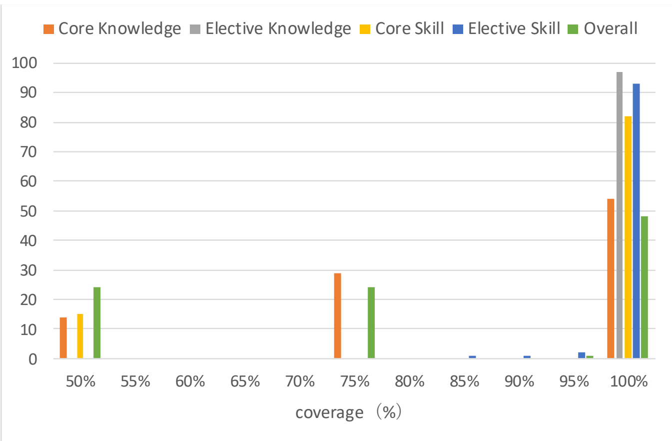

Fig. 2. Distribution of the Number of Programs for Each Coverage Value for Computer Engineering

Fig. 2 represents the distribution of the number of programs for each coverage value of Computer Engineering. There are some programs whose coverage values are less than 80%. This happens for the case of core knowledge and skill. Since sum of the required levels for core knowledge and skill are 4 and 2 respectively. This means that CE requirement is quite small for core knowledge and skill. Then the coverage values of core knowledge and skill tend to be high as long as an educational program teaches the limited set of knowledge and skill. On the other hand, the coverage values for elective knowledge and skill are generally high because the expected enrollment rate is 50% for CE. Then an education program can have high coverage values as long as they teach more than half of the elective knowledge and skill.

C. Software Engineering (SE)

There are 23 programs conforming to SE, which is the smallest number of conforming programs among five computing domains. As can be observed from Table VI, 96% of the conformed SE programs are also conforming to CS and IT. As we have discussed at subsection A, a class of conformed CS programs is a subset of conformed IT programs. Thus we can conclude that the class of conformed SE program is a subset of conformed CS program. Then the SE requirement is strictly stronger than the CS requirements. A conformed SE program is most likely a conformed CS and IT program.

TABLE VI. NUMBER OF CONFORMED PROGRAMS AND PERCEPTION OF THE SE RECOGNIZED PROGRAMS

	CS	CE	SE	IS	IT	Others	Total
Conformed	22	20	23	18	23	-	-
Perceived	7	2	0	2	4	8	23

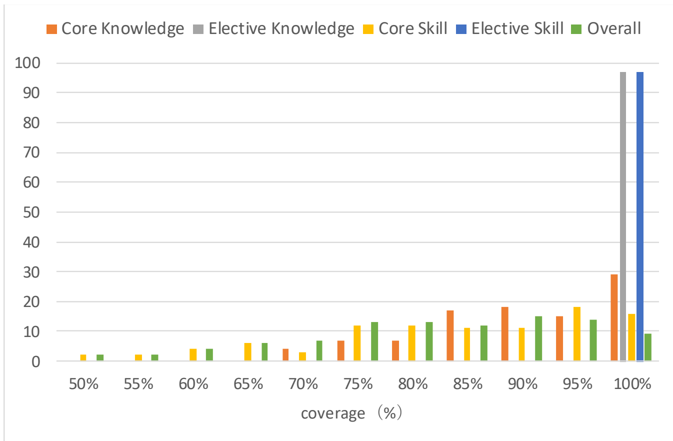

Fig. 3. Distribution of the Number of Programs for Each Coverage Value for Software Engineering

Fig. 3 represents the distribution of the number of programs for each coverage value of Software Engineering. As can be seen from the figure, the coverage value of elective knowledge and skill are generally high. This is mainly because that the expected enrollment rate is 50% so that an education program is required to teach half of the suggested topics. On the other hand, sum of the required levels of the core knowledge and skill are 77 and 85 respectively. An education program must cover 90% of the core topics so that many of the programs cannot be conformed to SE.

D. *Information Systems (IS)*

We find 38 programs conforming to IS. As can be observed from Table VII, 82% of the conformed IS programs are also conforming to IT. The reason is that both of IS and IT requirements focus on Domains (B)-2 (Information Representation Accumulation and Management) and (E)-1 (Technics for Information System Development) so that there are many common topics between IS and IT. Major difference between IS and IT are that IS focuses on defining requirements for information system and on designing the system, while IT focuses on development and administration of IT infrastructure within an organization. Currently the requirement levels of IS are typically less than or equal to those of IT. However, considering the difference between IS and IT, the IS requirements need to be raised particularly at the Domains (D)-1, (D)-2, (D)-3 and many of the domains in Section (E) in Table II.

TABLE VII. NUMBER OF CONFORMED PROGRAMS AND PERCEPTION OF THE IS RECOGNIZED PROGRAMS

	CS	CE	SE	IS	IT	Others	Total
Conformed	25	28	18	38	31	-	-
Perceived	13	1	0	5	6	13	38

Fig. 4 represents the distribution of the number of programs for each coverage value of Information Systems domain. The coverage values of elective knowledge and skill are generally high because the expected enrollment rate is 50% for IS. Although the sum of the level of core skills is 8 and is very small, the requested level of Domain (B)-2 is high as 4 so that more than 50% of the programs do not meet core skill requirements of IS.

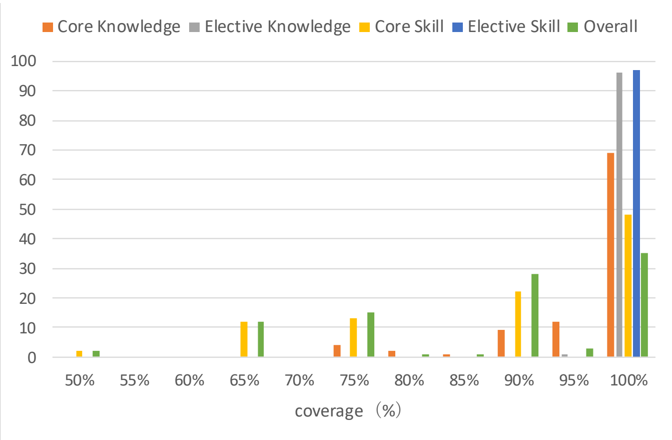

Fig. 4. Distribution of the Number of Programs for Each Coverage Value for Information Systems

E. *Information Technology (IT)*

There are 49 programs conformed to IT, which is the largest number of conforming programs among the five computing domains. As we have discussed at subsections A and C, the class of conformed IT programs almost contains the classes of conformed CS and SE programs. As can be observed from Table VIII, the number of conformed CS and SE programs among the conformed IT programs are 30 and 23 so that the class of conformed IT programs is considered to be the largest among these three classes. This means that the IT requirement is the weakest among the three domains: CS, SE and IT.

TABLE VIII. NUMBER OF CONFORMED PROGRAMS AND PERCEPTION OF THE IT RECOGNIZED PROGRAMS

	CS	CE	SE	IS	IT	Others	Total
Conformed	30	33	23	31	49	-	-
Perceived	17	5	0	8	4	15	49

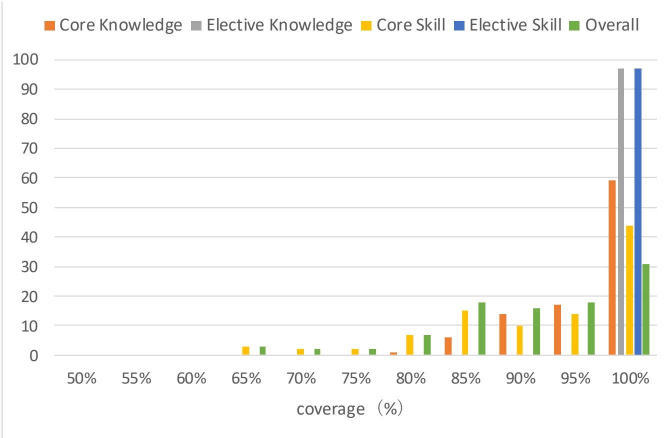

Fig. 5. Distribution of the Number of Programs for Each Coverage Value for Information Technology

We can observe that 67% of the conformed IT programs also conforming to CE. Although there is a similarity between IT and CE, CE generally requires higher levels of knowledge and skill on hardware topics. However most of the hardware topics are elective in CE so that many programs can conform to CE even if the achievement level on hardware topics are low. On the other hand, IT requires higher level of skills at the Domains (B)-2, (D)-1, (D)-2 and (D)-3 in Table II.

Fig. 5 represents the distribution of the number of programs for each coverage value of Information Technology domain. The coverage values of elective knowledge and skill are generally very high. This is because that the expected enrollment rate is 30%, which is the minimum value among the five domains. Although the sum of the levels for core knowledge and skill are 111 and 64 for IT, the requested levels are 2 in most cases so that it is not difficult for an education program to satisfy the IT requirement.

VII. Analysis of Unclassified Computing Programs

Table IX illustrates the distribution of the number of programs based on the number of conformed domains. We can observe that 28 programs do not conform to any of the five computing domains. On the other hand, we find 16 programs which conform to all of the five domains. We shall analyze these two types of programs in this section.

TABLE IX. Distribution of Programs based on the Number of Conformed Domains

0	1	2	3	4	5	Total
28	26	7	10	10	16	97

The maximum coverage value of the programs which do not conform to any of the existing domain ranges between 62.5% and 89.1%. The maximum coverage value is more than 80% for 17 programs. This indicates that the definition of the threshold value for the conformance to a particular computing domain greatly affects the result. Thus we need to carefully choose the threshold value to define conformance. Since the maximum coverage value of the programs always exceeds 60%, the value can be utilized for an education program to determine the closest computing domain to be developed.

There are 26 programs which conform to more than 4 computing domains. 80% of such programs conform to CS, SE and IT. As we discussed in Section V, a program conforming to SE also conforms to CS and IT. In such cases, a program may conform to multiple computing domains.

For the remaining case of the programs which conform to more than 4 domains, requirements of the conforming domains do not overlap. According to our accreditation experience, it is difficult for an education program to simultaneously satisfy requirements of multiple computing domains. Thus we consider that such programs may loosely interpret the achievement level defined in Table I so that the reported achievement levels may be higher than the actual levels.

VIII. Concluding Remarks

A. Research Result

We compare requirements of a computing domain and achievement of a computing program using a common BOK in this paper. We also made a preliminary comparison of 5 computing domains, CS, CE, SE, IS and IT; and the achievement survey responses from 97 education programs.

Our contribution can be extended to the countries other than Japan after common BOK is developed at these countries. In this sense, our work can be considered as a comparison framework between achievement and requirements for computing education.

B. Suggestion

A curriculum development committee can utilize our comparison and analysis framework to adjust requirement levels of their specific computing domain in order to provide a reasonable requirement to the educational programs. Since our comparison framework enables comparison between requirements of different computing domains, the committee can also identify specific requirements of their curriculum. Our framework can be utilized as a tool to encourage curriculum development.

From the viewpoint of an education program, it is recommended to utilize the coverage values of their curriculum for their intended computing domain. It is a usual case that the allowable effort is limited to provide computing education. Thus an education program must choose topics with high priority in order to maximize educational achievement with limited amount of effort. The coverage values proposed in this paper can be utilized to assign effort to the educational program in a systematic manner.

Our comparison framework can be applied to various types of computing curriculums such as different stage of education such as primary school, secondary school, high school and general computing education at college level. Since curriculum management throughout the entire education stages is quite important, we have a plan to extend the proposed framework for such purposes.

C. Future Work

Application of our framework to other countries is left as a future work. Actually many countries are developing common BOK in ICT domain so that our framework can only be applied after the BOK is established.

Ability of persons in ICT domain is modeled by a combination of knowledge, skill and competency as defined in ISO/IEC 24773 [8]. Our framework, however, currently treats only knowledge and skill, since competency is mainly developed through actual job and contribution to the organization and/or society is required to evaluate competency. Extension of our framework to treat competency is left as a future work.

Acknowledgments

This research is supported by the Japanese Ministry of Education and JSPS KAKENHI Grant Number 16K01022.

We appreciate the faculty members at computing department and curriculum committee members for their cooperation in responding to our survey.

References

[1] T. Kakeshita, "National survey of Japanese universities on IT education: overview of the entire project and preliminary analysis," Proc. 9-th Int. Conf. on Computer Supported Education (CSEDU 2017), pp. 607-618, 2017.

[2] T. Kakeshita., "National survey of Japanese universities on computing education: analysis of departments majored in computing discipline," *Olympiads in Informatics*, Vol. 12, pp. 69-84, 2018. DOI: http://doi.org/10.15388/ioi.2018.06

[3] M. Hagiya, "Defining informatics across Bun-kei and Ri-kei," *Journal of Information Processing*, Vol 23, No. 4, pp. 525–530, 2015. DOI: http://doi.org/10.2197/ipsjjip.23.525

[4] ACM, IEEE-CS, AIS, Computing Curricula Recommendations. Available at https://www.acm.org/education/curricula-recommendations

[5] IEEE-CS, EITBOK - Enterprise Information Technology Body of Knowledge, 2017.
Available at https://www.computer.org/web/education/itbok

[6] Austrarian Computer Society (ACS), ACS Core Body of Knowledge for ICT Professionals (CBOK), 2015.
Available at https://www.acs.org.au/content/dam/acs/acs-skills/The-ACS-Core-Body-of-Knowledge-for-ICT-Professionals-CBOK.pdf

[7] European Commission DG Internal Market, Industry, Entrepreneurship and SMEs, The European Foundational ICT Body of Knowledge, 2015.
Available at http://www.digitaleurope.org/Document-Download/Command/Core_Download/EntryId/925

[8] ISO/IEC DIS 24773-1: Software and systems engineering - Certification of software and systems engineering professionals - Part 1: General requirements, 2018.
available at https://www.iso.org/standard/69724.html

[9] C. Bell, R. Mills, K.Fadel, "An Analysis of Undergraduate Information Systems Curricula: Adoption of the IS 2010 Curriculum Guidelines," *Comm. of the Association for Information Systems*: Vol. 32, Article 2, 2013.

[10] D. Hwang, Z. Ma, M. Wang, "The Information Systems Core: A Study from the Perspective of IS Core Curricula in the U.S.," *Information Systems Education Journal,* 13(6), pp. 27-34, 2015.

[11] F. Burstein, J. Richardson, A. Hol, J. McGovern, "A Study of Australian Undergraduate IS Programs and Curriculum Final Report (DRAFT)," Austrailan Council of Professors and Heads of Information Systems, 2017.

[12] H. Topi, J. S. Valachic, R.T. Wright, K. Kaiser, J.F. Nunamaker, Jr., J.C. Sipior, and G.J. de Vreede "IS 2010: Curriculum Guidelines for Undergraduate Degree Programs in Information Systems," *Comm. of the Association for Information Systems*, (26) Article 18, pp. 359– 428, 2010.

[13] K. Kawamura, "Computing curriculum standard J07: computing in general education (J07-GE)," *IPSJ Magazine*, Vol. 49, No. 7, pp. 768-774, 2008. (in Japanese)