Olympiads in Informatics, 2018, Vol. 12, –

DOI: 10.15388/ioi.2018.

National Survey of Japanese Universities on Computing Education: Analysis of Departments Majored in Computing Discipline

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Abstract. We conducted the first national survey of computing education at Japanese universities in 2016. In this paper, we report the survey result of the computing education at a department or a course majored in the computing discipline. The survey covers various aspects including program organization, quality and quantity of educational achievement, students, teaching staff and computing environment. Thus the survey result is expected to be a good fundamental to develop realistic computing curricula and accreditation criteria in Japan. The estimated number of computing departments and students in Japan 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. The information processing society of Japan (IPSJ) and the Japanese Ministry of Education (MEXT) utilize the survey result to develop a new computing curriculum standard J17 and national policy of computing education respectively.

Keywords: web-based survey and analysis, college level education, curriculum development and analysis, accreditation criteria development, computing education, quality assurance in education.

1. Introduction

Computing education is essential at modern universities since information technology is expected as a powerful innovation driver as well as an essential infrastructure of the modern society. There are four types of computing education in Japanese universities.

1. Computing education at a department or a course majored in computing discipline.
2. Computing education at a non-IT department or a course as a part of their major field of study.

3. General computing education for all university students typically at the first or second academic year.
4. Computing education to obtain high school teacher license on computing subjects.

We conducted a national survey of Japanese universities on computing education in 2016 (Kakeshita, 2017). 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 is actually the first national survey in Japan since there was no widely accepted definition of computing education. This situation is essentially the same at other countries so that we are not aware of a similar survey collecting comparable level of detailed data as our survey.

The Science Council of Japan developed the reference standard of informatics (Hagiya, 2015) for university education in 2016. The reference standard provides a common body of knowledge (BOK) for college level computing education and the Japanese government accepted this as a definition of computing education. Thus we shall use the reference standard as the definition of computing education in this paper.

In this paper, we report and discuss the result of the survey type A for computing education at a department or a course majored in computing discipline. The survey is designed to analyze and understand current status of computing education at Japanese universities from various aspects including program organization, quality and quantity of educational achievement, students, teaching staff and computing environment. The analysis result will be expected as a fundamental to develop reasonable curriculum guidelines and accreditation criteria for computing education. The analysis also clarifies the difference of the five major computing domains, CS, CE, SE, IS and IT, which are developed separately by different community.

The Information Processing Society of Japan (IPSJ) utilized the result to develop the new J17 curriculum standard for computing education in 2017. The Japanese Ministry of Education (MEXT) will utilize the survey result to improve the national policy of computing education.

2. Survey Plan

2.1. *Survey Questions*

The following is the list of questions for survey type A. As the reader can understand from the list, our survey covers various aspects of computing education. These questions are prepared by considering the Japanese standards for establishment of universities and our accreditation experience of computing programs in Japan.

- Name of university, faculty, department and course.
- Program organization.
  - Day time, night or remote program.

  - Academic discipline of the program such as engineering, social science and humanities.
  - Specific computing domain including CS, CE, SE, IS and IT defined in CC2005 (JTF, 2005).
  - Required number of credits for graduation.
  - Number of subjects provided.
- Quality and quantity of educational achievement.
  - See Section 2.2 for detail.
- Enrolled students.
  - Regular academic years of the program.
  - Number of students.
  - Student's choice of career after graduation.
- Teaching Staff.
  - Number, educational background, current specialized field, tenure of faculty members.
  - Number and workload of support staff.
  - Number and workload of teaching assistant students.
- Computing environment.
  - Educational computer system.
  - Utilization of Student's own PC.
  - Educational programming language.
- Other topics (If any).
  - Future plan and strength of the program.
  - Utilization of IT certification and/or qualification.
  - Special remarks.

2.2. *Survey of Quality and Quantity of Educational Achievements*

The survey of quality and quantity of educational achievements is the core of our survey. We define six achievement levels for knowledge and skill defined in Table 1. These levels are used to define quality of education.

We also define a BOK based on the reference standard of informatics (Hagiya, 2015) and additional topics related to general computing education (Kawamura, 2008). The BOK contains 90 topics classified by 21 domains as represented in Table 2. The BOK is used to precisely define educational contents of each program.

Although CC2005 (JTF, 2005) defines five computing domains to define typical computing curriculums, corresponding BOKs are different depending on the domain. We define the BOK instead of using the five different BOKs. We also expect to find educational programs other than the typical ones. Common BOK is also useful to clarify the difference among the existing five domains (Kakeshita and Ohtsuki, 2014).

It is usual that a computing education as the major domain is performed at a department or a course of a department. Thus a department or a course responds to the survey. Each organization answers expected knowledge and skill levels of the students at each

Table 1

Knowledge and Skill Level Definition

Level	Knowledge Level Definition	Skill Level Definition
0	Not taught (unnecessary or already taught at general computing education)	
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 term	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 term	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 topic 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 others

Table 2

Common BOK Organization

Source	Section	Domain	# of Topics
J07-GEBOK	General Computing Education		9
Reference Standard for Informatics	(A) General Principles of Information		6
	(B) Principles of Information Processing by Computers	Information Transformation and Transmission	4
		Information Representation, Accumulation and Management	4
		Information Recognition and Analysis	4
		Computation	6
		Algorithms	8
	(C) Technologies for constructing computers that process information	Computer Hardware	3
		I/O Device	4
		Fundamental Software	3
	(D) Understanding humans and societies that process information	Process and Mechanism for Information Creation and Transmission	2
		Human Characteristics and Social System	3
		Economic System and Information	2
		IT-based Culture	2
		Transition from Modern Society to Post Modern Society	2
	(E) Technologies and organizations for constructing and operating systems that process information in societies	Technics for Information System Development	7
		Technics for Information System Utilization	6
		Social System Related to Information	2
		Principle and Design Methodology for HCI	4
	Professional Competency for IT Students		3
	Generic Skill for IT Students		6

topic of the BOK. At the same time, the organization answers the total number of students taking a subject teaching each topic. As a result, quality and quantity of education at the organization can be summarized through the survey.

2.3. *Survey Process*

We prepared the survey in October 2016. At first we defined the survey questions and set up the web-based survey system (Kakeshita, 2011). We utilized the web-based survey since we did not exactly know the actual organizations for this survey in advance. After preparing various document 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.

The survey was executed for two months starting at the beginning of November 2016. Each survey responder of survey type A must first register to the web system and then answer the questions listed in Section 2.1. We also provided FAQ at the survey web site and sent e-mail responses to each of the questions from the survey responders.

After closing the survey, we reviewed the collected answers and requested the responders for possible correction of the incomplete answers.

3. Overview of the Survey Result

3.1. *Response Rate Analysis*

We collected 296 answers for the survey type A. We reviewed the answers and found that 17 are invalid because of the two reasons. (1) The number of required credits is less than 30, which is 25% of the minimum credits defined by the Japanese standards for establishment of universities. (2) The name of the department does not indicate computing discipline. After contacting the 17 organizations, we obtained permission to exclude them from the computing departments. Therefore the total number of answers is 279.

Among the 279 answers, 82 come from national universities and 166 from private universities. 31 answers come from public universities which are founded and run by local government such as city or prefecture.

Each answer is provided either by a faculty, collection of departments, single department or a course. Thus the number of answers does not directly represent the actual number of computing departments in Japan. We examined the answers to have Table 3 representing the number of universities, faculties and departments having computing department or course.

Table 3
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

There is a council of informatics departments (DI-Council) in Japan whose academic discipline is natural science or engineering. 151 departments join the DI-Council. 127 departments (84.1%) also respond to the survey so that we can estimate that the response rate of the survey is about 85%. Considering the response rate, we estimate that the number of computing departments in Japan is approximately 300. This means that there are quite a large number of computing departments which we are not aware in Japan.

The response rate 85% 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. Each organization responds to the survey as a part of their job.

3.2. *Student Enrollment*

Table 4 represents the number of students majored in the computing discipline classified by academic discipline and specific domain within computing.

Total number of students is 26,112. Considering the response rate, the total number of computing students is approximately 28,000 in Japan. The numbers of male and female students are 21,529 and 4,583 respectively. 47.3% of the female students belong to 20 universities so that the distribution is highly skewed. Since IT service is widely

Table 4
Distribution of Computing Students Classified by Academic Discipline and Computing Domain

Academic Discipline	CS	CE	SE	IS	IT	Others	Total
Engineering	5,549	1,632	78	1,664	997	3,715	13,635
Social Science	40			419	742	3,453	4,654
Physical Science	730			100		224	1,054
Humanities					125	318	443
Pharmacy and Nursing				170	70	56	296
Art			65		78		143
Education						40	40
Others	449		157	20	665	4,556	5,847
Total	6,768	1,632	300	2,373	2,677	12,362	26,112

utilized in the modern society, it is expected that more female students study computing discipline as their major in order to promote further innovation using IT. The number of IT professionals is approximately 1 million in Japan so that more students are expected to learn computing discipline as their major.

According to US educational survey (NCES, 2017), the Bachelor's degree in computer and information science is 59,581 in 2014-15 so that the number of computing students in Japan is approximately 43.8% of that of US. Since the population of Japan is 39.0% of that of US, the ratio of computing students against the population is almost the same at both countries.

The following is the observations we found in Table 4:

- The second largest academic discipline is "Others". The corresponding departments are interdisciplinary, i.e. belonging to two or more disciplines. This indicates the diversity nature of the computing discipline which cannot be covered by an existing discipline.
- 26.5% of the departments are teaching computer science (CS) and 32.3% are teaching one of the other existing computing domains. However, 41.2% of the departments cannot be covered by a single domain. Appropriate curriculum guidelines are expected to be developed for these departments.
- Although CS and CE are mainly taught at engineering or physical science departments, IS and IT are also taught at social science and other departments. We consider that there is a historical reason for this. Computing education, particularly CS and CE, has been provided mainly at a department majored in engineering or natural science. However the computing domain is expanding so that new domains such as IS and IT are emerging. The departments majored in social science and humanities also take the responsibility to provide IS and IT education.

Table 5 represents the computing student's career selection after graduation. The number of students does not coincide with Table 4 because of the incomplete answers. It should be noted that career selection is completely different at national, public and private universities. 52.8% of the students enter a graduate school at national university, while 9.9% at private university. A possible reason is that the tuition fee of a private university is typically two or three times higher than that of the national or public universities. It is also recognized that many of the students enter the graduate school of the same university they graduated. This means that 6-year education consists of undergraduate and master course education can be effectively introduced mainly at national universities. This also implies that mobility of the student is rather limited in Japan.

Table 5
Student's Career Selection after Graduation

Career Selection	National	Public	Private	Total
Graduate school in computing discipline	2,620	388	1,309	4,317
Graduate school in other disciplines	338	57	237	632
Hired at company, government or school	2,409	1,093	12,198	15,700
Others (including unknown)	231	52	1,828	2,111

3.3. Number of Credits for Graduation

In Japan, an undergraduate program must contain at least 124 credits to obtain a Bachelor degree. 1 credit requires 45 hours of learning including class. Typical curriculum is composed of general education at university level (typically 20 to 40 credits) and common education at faculty level (typically 10 to 20 credits) in addition to the specialized education at a department or a course. An educational institution must first assign credits to each component. Depth and width of the education is greatly affected by the allocated credits.

Fig. 1 represents the distribution of the required number of credits for the specialized computing education. The distribution is illustrated using a box plot and provides a realistic restriction to design computing curriculum for each domain. For example, typical CS curriculum is composed of 75 to 100 credits. Observing this distribution, it is recommended to design a CS curriculum guideline between 50 and 60 credits. This will allow freedom to design computing curriculum considering strength and background at each educational program while preserving quality assurance of computing education among many of the CS departments. Similar discussion is possible at other domains.

4. Educational Achievements

We shall analyze the educational achievement, i.e. quality and quantity of education, in this section. We collected 97 answers of the quality survey and 67 answers of the quantity survey. Although the number of collected answers is smaller than the number of responses to the survey, it is comparable to 75 which is the estimated number of samples calculated under the assumption of universe size 300 and 10% statistical error. Therefore our discussion can be statistically reasonable.

We define educational effort of a program for a certain topic of the BOK by the multiplication of average level value and the number of students learning the topic. We thus define two types of effort values to teach knowledge and skill.

Fig. 2 illustrates the effort distribution of each computing domain. Each of the effort values are summed up for each section as defined in Table 2 in order to clarify characteristics of each domain. Although skill effort values are used in Fig. 1, correlation

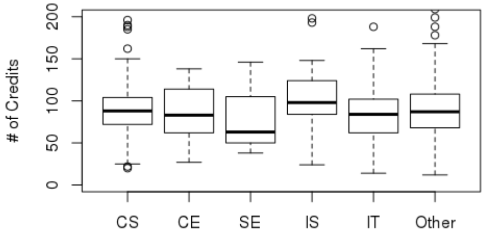


Fig. 1. Distribution of the Number of Credits for Graduation at Each Computing Domain.

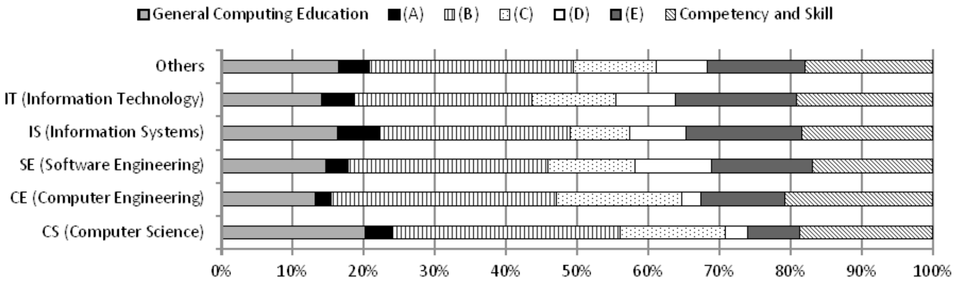


Fig. 2. Educational Effort Distribution of Skill Teaching for Each Computing Domain.

coefficient between skill and knowledge effort values is 0.97 so that distribution of the knowledge effort values is similar.

Major difference of the effort distribution among the domains arises at the sections from (B) to (E). In CS and CE, traditional contents defined in (B) and (C) are dominant. On the other hand, educational program of IS and IT focus more on (D) and (E). As we discussed in Section 3.2, there are some IS and IT departments in social science where (D) is contained in their major subjects. The contents in (E) can also be taught at social science departments because system operation is included in (E).

We also calculated the effort at each domain defined in Table 2. The top 3 domains with the highest effort are as follows. Many of the computing departments focus on these educational topics.

- General Computing Education
- Generic Skill for IT Students
- Algorithms

These domains are relatively easy compared to other domains. We consider that there are two reasons that the computing departments focus on these domains. One is the shortage of teaching staff who can teach high level computing topics. The other is the declining academic ability of the students due to the increase of the percentage of students who enter university or college in Japan.

On the other hand, the topics other than the above three can be considered as the contents which an educational institution can claim their originality. Since the computing discipline is quite large, each institution is expected to focus on particular domains which they have strength.

Fig. 3 summarizes the overall distribution of the skill levels of each computing domain. The skill level is summarized for each section of the BOK defined in Table 2. The skill level distribution at each section characterizes each computing domain. We can observe that typical skill level of general IT education is at most 2 so that students are taught with some exercise. However the typical skill level of competence exceeds 2. The difference comes from that competence is usually taught during the graduation thesis project while general IT education is taught at the first or second academic year. We also observe that the average knowledge level is around 3 so that we can expect that a typical student can explain the meaning of a technical term.

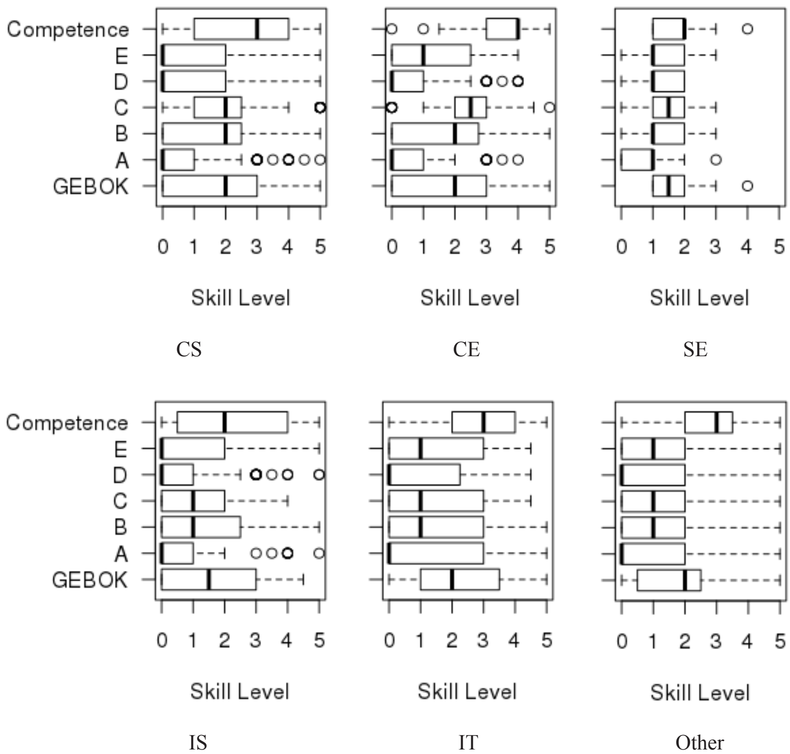
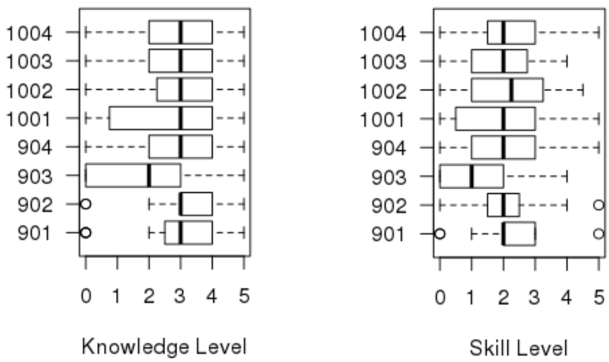


Fig. 3. Overall Distribution of Skill Levels of Each Computing Domain.



901: Data, 902: Data Structure, 903: Data Type, 904: Database, 1001: Signal Processing, 1002: Pattern Recognition, 1003: Machine Learning, 1004: Data Mining

Fig. 4. Detailed Distribution of Knowledge and Skill Levels of CS Domain (Selected Topics of Section B).

Fig. 4 represents the detailed distribution of knowledge and skill of the selected topics of section B for the CS domain. The readers can observe that the achievement levels of topic 903 (data type) is rather weak compared to other topics. Although we have similar distributions for the other combination of the other computing domain and topics, they are omitted due to the space limitation. The box plot provides top 25%, median (top 50%) and top 75% values of the levels so that the readers can consider desirable, typical and minimum levels for each section and/or topic.

These distributions are useful both for the computing departments and curriculum development. From the viewpoint of a computing department, the distribution is useful to analyze strength and weakness of their computing program for each topic. From the viewpoint of curriculum developer, the distribution can be utilized to define realistic requirements for the achievement levels at each topic. Such recommendation about the achievement level can also be utilized at computing accreditation.

5. Teaching Staff

5.1. *Faculty Member*

Table 7 represents the number of faculty members teaching at computing departments. Faculty members outside of the department are in charge of 23.2% of the classes. This indicates shortage of teachers at computing departments.

The number of organizations is 119 (49.6% of the valid answers) that the number of computing department graduates is less than 50% of the number of faculty members. The number of organizations is 68 (28.3%) that the number of computing department graduates is less than 30% of the faculty members. It is our concern that systematic computing education may not be enough for the graduates of non-computing departments.

We also observe that the ratio of the faculty members whose current major is computing is more than that of the ratio of computing department graduates. This means that a significant number of faculty members changed their major after graduation. However we also observe that the number of organizations is 59 (24.6%) that the ratio

Table 7

Number of Faculty Members at Computing Departments

	Total	Computing Dept. Graduates	Current Major is Computing	# of Classes in charge
Faculty members of the department (with tenure)	4,281	2,315 (54.1%)	2,943 (68.7%)	13,824
Faculty members of the department (without tenure)	643	341 (53.0%)	397 (61.7%)	1,459
Faculty members of other departments or faculties	1,200	459 (38.3%)	520 (43.3%)	2,461
Part-time instructor (outside of the university)	1,949	653 (33.5%)	940 (48.2%)	2,275

of faculty members is less than 50% whose current major is computing. Some of them answered that "the number of faculty members majored in computing is not enough" or "having help of the faculty members belonging to other departments". We expect these organizations to have academic positions to hire more faculty members who have enough ability to teach contemporary computing technology.

5.2. Support Staff and Teaching Assistant

Although 78 organizations (67.5% of the valid answers) employ a support staff for computing education, 162 do not employ support staff. We also find that 49 organizations (20.4%) do not employ teaching assistant student. Major reason of these is considered as financial restrictions. Support staff and/or teaching assistant are essential in order to effectively support students during exercise and experiments to achieve expected skill levels. It is expected for the government and university to provide financial support.

The support staffs assist 541 classes with 1.6 staff per class. The teaching assistants assist 3,770 classes with 77.8 man-hours per class. Thus teaching assistant students are more important than support staffs at many classes. We found that some of the universities located in a metropolitan area employ students belonging to neighboring universities as their teaching assistant.

5.3. Student/Teacher Ratio

Fig. 5 represents the distributions of the number of students per teacher of the computing domains. The box plot represents top 25%, median (50%) and 75% values so that these values can be utilized to determine reasonable accreditation criteria (minimum requirement and recommendation). The student/teacher ratio is less than 10 at many of the organizations. However we found 23 organizations whose ratio exceeds 10. It is expected to keep appropriate number of students per teacher to provide enough care for the students.

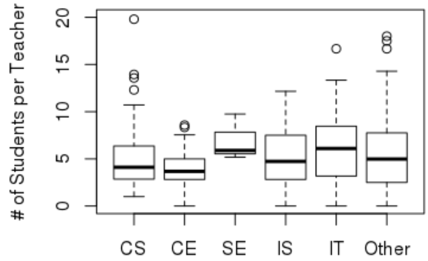


Fig. 5. Distribution of the Number of Students per Teacher of Each Domain.

6. Computing Environments

Table 8 represents situation of computing environments classified by educational computer system and student PC purchase. The item “does not use computer system” indicates that the department etc. does not use educational computer system provided by the university.

24.4% of the organizations have their own educational computer system so that they can fully control the system. However 23.6% do not have any computer system. 49.5% utilize shared computer system at various levels. This is because the computer system budget tends to be reduced at many universities. However, as demonstrated in Table 9, we find that utilization of computer system greatly affects average knowledge and skill levels of the students. The reader can observe from Table 9 that the average levels are similar between the institutions with private and shared educational computer systems. Although it is more difficult to control the shared computer system, some of the computing departments can effectively control the system in the case that they have faculty members majored in computer system administration.

Although BYOC concept is widely known, only 24.4% of the organizations require students to purchase their own PC. 67.4% leave students to decide whether to purchase PC. 52 organizations do not recommend students to purchase PC although they do not have educational computer system. We are planning to investigate the detailed reason as a future work.

Table 8
Educational Computing Environment at Computing Departments

	Required to Purchase Student PC			Student PC Recommended	Other	Total
	(Dept.)	(Faculty)	(Univ.)			
Private Computer System	11	3		7	47	68
Shared Computer System (University Level)	2	5	14	2	48	71
Shared Computer System (Faculty Level)		10	1	7	21	39
Shared Computer System (Campus Level)	2	1	1	5	19	28
Does not use Computer System	3	3			1	7
No Computer System	3	1	7	3	52	66

Table 9
Relationship between Educational Computer system and Average Knowledge and Skill Levels

Educational Computer System	Average Level	
	Knowledge	Skill
Private System	1.67	1.05
Shared System	1.67	1.08
No Computer System	1.20	0.73
Total	1.63	1.04

Table 10

Top 10 Educational Programming Languages

Programming Language	Score	Programming Language	Score
1. C	826.5	6. SQL	100.5
2. Java	602.5	7. Python	87.5
3. C++	205.0	8. Visual Basic/VBA	82.0
4. JavaScript	168.5	9. PHP	72.0
5. Assembly Language	117.0	10. Ruby	31.5

Table 10 represents the top 10 educational programming languages. The score is estimated by the weighted sum of the answers with priority. C and Java are the traditional choices as structured and object oriented language. C++ is utilized as “better C” because it supports simplified I/O (cin/cout) and STL (standard template library). Python and Ruby are utilized as simple languages with high software productivity.

The following is a list of comments from the organizations. Several difficulties can be found from the comments. It is expected to provide appropriate support for these organizations:

- We quitted mandatory programming courses so that its effect is under investigation.
- Some students do not understand importance of software engineering despite of complexity of software development.
- If a student perceives that he is not good at computer programming, the fact greatly affects student motivation.

7. Educational Efforts

Many organizations continuously improve their education program by curriculum updates or by faculty reorganization. Some of the typical educational activities collected through the survey are listed below:

- Introduction of good educational practices: PBL (problem/ project based learning), active learning, presentation of student research papers at academic societies, etc.
- Cooperation with industry or other universities.
- Obtain accreditation by JABEE (Japan Accreditation Board for Engineering Education).
- Adoption of new computing curricula such as CS2013 (JTF, 2013).

We also find activities related to certification or qualification in the computing discipline as listed below. Such IT qualifications will be useful for the students to get a job after graduation.

- Curriculum design considering typical IT qualification such as JITEE (IPA, 1969) which is a large qualification with 500,000 applicants each year provided by the Japanese government.
- Student support to obtain IT qualification: give credits to qualification holders, support seminar, funding support, etc.

8. Concluding Remarks

The analysis of the survey result will be a good input to design computing curriculum and accreditation criteria to improve computing education in Japan. Similar survey and analysis will be also valuable in other countries.

Information technologies and social situation are rapidly changing. Computing departments are receiving many educational requests from the industry and the society. Some of them are AI, big data, data science, IoT, innovation using IT and information security. We found that many computing departments are trying to respond to these requests through the survey.

We can observe the entire picture of the computing education at Japanese universities through the survey. Although several problems are discovered, IPSJ is willing to improve the current situation through development of new computing curriculum standard J17 and cooperation with Ministry of Education, Japan.

Acknowledgments

This survey project is supported by the Ministry of Education, Culture, Sports, Science and Technology, Japan. The authors greatly appreciate the faculty members and the administration officers of the universities who take time to respond to the survey. This research is also supported by JSPS KAKENHI Grant Numbers 16K01022 and 17K01036.

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