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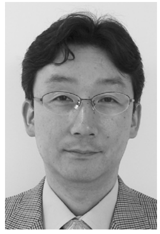
Trends and Issues in Computing Curriculums



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1 Introduction — Introduction to issue

Most activities, whether industrial, public, academic research or everyday life, rely on the technical advances of software.

Software production in Japan totals approximately 20 trillion yen per year. It produces extensive ripple effects in various industries, because of its high growth and sheer scale. More than 10,000 university students receive computing-related professional training every year. Skills that these students acquire are also important from the standpoint of the competitiveness of Japanese industries.

Technological advances over the past ten years have produced environmental concerns, especially involving software production. Accordingly, there is a gap between the content of education offered at universities and the realities of industries.

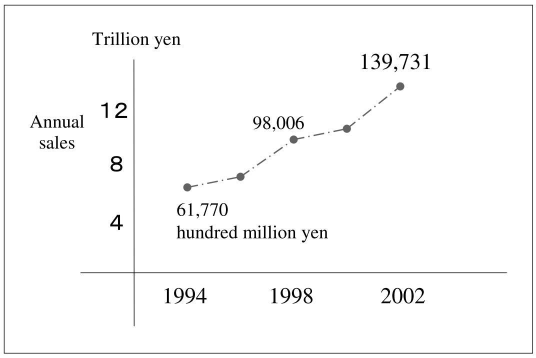
This article investigates the present state of the model curriculum adopted by information processing-related faculties and departments such as the Computer Science Department in order to analyze the above issue. This report also explains the present circumstances surrounding the industrial world and the educational institutes of Japan and the US, with a specific focus on the field of software engineering, the significance of which has greatly increased in recent years. Finally, recommendations for a technology policy are presented.

2 Present position of software industry

This section provides data that indicate a quantitative expansion of software production. According to statistics from the "Survey of Selected Service Industries of 2003 (information service business version)" released by the Ministry of Economy, Trade and Industry, the amount of sales in the information service business obtained during the fiscal year 2003 was approximately 14 trillion yen. The number of employees showed roughly the same pattern as the annual sales to reach 570,000 as of the fiscal year 2003. Figre 1 shows the annual sales in the field of information service for the past ten years.

Software can be divided broadly into (i) business software, (ii) package software, (iii) embedded software and (iv) game software. Business software represents the development of so called ERP(Enterprise Resource Planning) software used, for example, for production

Figure 1 : Change of annual sales by information service business



Source: Prepared by the author based on statistics released by the Ministry of Economy, Trade and Industry.

or sales management. Package software often describes the development of software components used for selected businesses. A software development service that provides prepackaged applications that are adjusted for client companies' operations is also included in this category. Software (i) to (iv) are in the order of production value.

Who are target customers for software development and other services? One survey shows that customers are from a wide area of industry, with the service industry accounting for 22.4% of all customers, the finance industry for 18.4%, the manufacturing industry for 13.6%, the government and other public offices/prefectural and city governments for 12.8%, the telecommunications industry for 7.8% and other businesses for 7.7%.

Other software products are not included in the above statistics. For example, software is often developed when a new production line is introduced at a manufacturing premise. Such software is not included in the above statistics. Engine control software and other embedded software are also excluded. Software that does not fall under the category of "information service business" is estimated at a few trillion yen. If such software is included, Japanese software production is estimated at approximately 20 trillion yen.

In fact, the development of custom-made software to meet various needs of client companies constitute substantial portion of software production of approximately 20 trillion yen, accounting for nearly 80% of total software production. To support the future software production industry, more than 10,000 students receive processing training at universities or graduate schools every year.

3 Significant changes in information technology and software

This section considers qualitative changes in software production. As discussed in the previous section, software production expanded as client-server information systems that integrate Internet and Web-based technologies spread into the core business of companies and various other social activities.

"Information processing" power that we enjoy in our daily life has dramatically increased over the past ten years. In 1977, the average processing rate for average modern personal computers was 100 MHz in clock frequency, which has increased to a few GHz today. In addition, about 9.2% of households had Internet access by the end of 1997. By the end of 2002, only five years later, the number of Internet users reached 54.2% and became the majority[2]. Processing rates for average access lines increased from a few or dozens of Kbps to dozens of Mbps during the same period. If information-processing power can be calculated by multiplying the processing rate by the volume of communication, it has increased by tens of thousands of times during the previous five years. In addition, this tremendous processing power has spread widely from laboratories into households and offices. Today, software plays increasingly important roles in social activities, due to increases in information processing power.

For example, tailor-made therapy is considered important in the field of medical technology today. In order to put it into practice, it is necessary to establish a system that enables distribution, use, and management of a huge amount of patient personal information. Without using the Internet and Web-based technologies, as well as a large-scale database and safe information exchange networks, there would be no tailor-made therapy.

Another example is "electronic shops" that offer product information through Web sites. A growing number of companies are introducing business-oriented package software such as ERP (Enterprise Resource Planning), CRM (Customer Relationship Management) and SCM (Supply Chain Management) for information management. These software packages also run on the client server system using Web-based technologies.

4 US response

Information processing-related educational organizations in North America responded quickly to such changes in technological trends.

This section briefly explains developments in North America.

Initially, information processing-related disciplinary was considered "computer science" derived from mathematics and electrical engineering. "Software engineering" has always been considered a part of computer science, and therefore a growing gap has developed between a career path and the acquired knowledge of graduates who majored in software engineering. Consequently, claims were made that computer science and software engineering should be treated separately as an independent subject[7,8].

In the US and Canada, active discussions have been pursued concerning the positioning of computer science and peripheral engineering subjects and the role of the curriculum since the second half of the 1990's. Today, the "engineering aspect" is becoming more important in average computing education.

4-1 Model curriculum

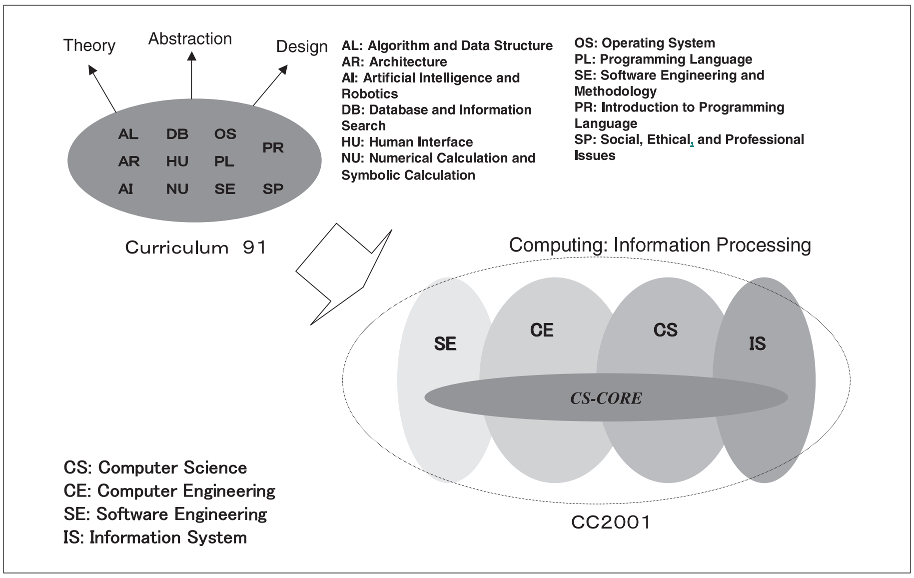
The following is an outline of the model curriculum. ACM (Association for Computing Machinery) and IEEE/CS (The Institution of Electrical and Electronics Engineers, Inc./Computer Society) are the world's biggest society in the field of computer and in the field of electrical and electronics engineering, respectively. Since the 1960's, they have developed a few model curriculums together. After several attempts, CC1991 was developed in 1991. In 2001, ten years after the development of CC1991, the latest model curriculum CC2001 (Computing Curriculum 2001) was developed.

CC2001 divides computing*1 clearly into four disciplines, CS (Computer Science), CE (Computer Engineering), SE (Software Engineering) and IS (Information System). CS provides a mathematical background into information processing such as algorithm and data structure. CE aims to use computers for numerical calculations, graphics, and other technical purposes. IS handles relationships between information processing systems and corporate and economic activities. Finally, SE aims to acquire skills required for software production.

CC2001 consists of a group of subject components that belong to each of the sub-fields. Components of the curriculum depend on the direction of an educational institute. Figure 2 shows changes in curriculum at the time of transfer from "Curriculum 91" to "CC2001" in a conceptual way. CS is positioned as a "core" for all four disciplines.

CC2001 stipulates that CE and SE belong to engineering, and CS and IS to science. In the context of CC2001, "engineering" and "science" differ from what the "faculty of engineering" and the "faculty of science" represent in Japan. These words seem to imply "technology and skill" and

Figure 2 : Conceptual diagram of curriculum transition - from "Curriculum 91" to "CC2001"



Source: Prepared by the author based on References[3].

"science and research", respectively.

4-2 Human resources required in industry

Based on the technological changes, the model curriculum CC2001 investigated human resources that would be in greater demand in connection with information processing. The investigation revealed that human resources are expected to possess specific skills, as shown in Table 1. For example, skills that fall under the category of 1 to 3 of Table 1 are essential for designing and building a client-server system described above. The category 5 points out the importance of providing information technology education at an early age.

In order to respond to the need for developing such human resources, the content of computing education at universities was determined. Table 2 shows new items that cannot be found in previous model curriculums. This table promotes a greater understanding of the growing importance of a relationship between information processing and the corporate activities in social life, as well as a relationship between information processing and information infrastructure that constitutes social infrastructures. It was difficult to acquire these skills in the framework of previous model curriculums.

Table 2 : Items included in a curriculum due to technologica changes in the second half of 1990's

A	World Wide Web and its application
B	Networking technology, with TCP/IP based ones in particular
C	Graphics and multimedia
D	Embedded system
E	Relational database
F	Interoperability
G	Object-oriented programming
H	Use of sophisticated application programmer interface (APIs)
I	Human - computer interaction
J	Software safety
K	Safety and encoding method
L	Application area

Source: Prepared by the author based on References[12].

Table 1 : Human resources to be in greater demand at the time of technological change

1	Programmer who is familiar with multipurpose type relational database systems and multipurpose enterprise resource planning package software in particular.
2	Programmer and designer with experience in object-oriented and Java languages.
3	Experts in Web and electronic commerce.
4	Network designer.
5	High school teachers, instructors who teaches information at vocational technical schools or undergraduate programs at universities.
6	Manager and project leader.

Source: Prepared by the author based on References[12].

4-3 Example of advanced software engineering education

In the US and Canada, undergraduate education are generally devoted to "engineering" or practical education, and graduate schools focus on providing "science" education. The faculty of "computer science" and that of "computing" accept more students than other faculties. In addition, graduates of these faculties have more choices for disciplines when they proceed to graduate schools. These factors encourage students to apply an acquired knowledge of and skills for information processing to many different fields.

Information processing-related faculties in US and Canada are often called the "Faculty of Computer Science." Students study CS as a core subject in the Faculty of Computer Science, and then proceed to a graduate school to become a researcher in the CS discipline. That is the typical career path for the graduates of the Faculty of Computer Science. As software plays an increasingly important role in industrial activities, there is a new career possibility. Students who study software engineering, for example, begin their career by managing and operating a project to develop enterprise resource planning software, before rising to the position of CIO[9].

The following is an example of education practice in the discipline of advanced software engineering in the US. Objectives of the discipline of software engineering are design and production of software. For that purpose, it is important to cultivate knowledge of software engineering by providing courses for "software life cycle and process model," "examination of requirements, rapid prototyping," and "knowledge of tools for modeling, test and product control," in addition to programming exercises.

Carnegie Mellon University provides the first example[10]. Carnegie Mellon established its SEI (Software Engineering Institute), which was financed by the Department of Defense. SEI conducts practical research and provides many practical educational programs to professionals. For example, in exercises called "pair programming", an implementer and verifier of functions work together to develop a program. As there is a growing demand for the quality of programs, performance verification-oriented production is considered an advanced skill.

Carnegie Mellon collaborates with companies to provide various practical seminars. In these seminars, students analyze actual business demand and develop software design specifications. They then perform programming based on a developed specification. It is as though students are undertaking a "virtual contract" to develop software to meet the requirements of companies. Students also practice various techniques such as PSP/TSP, reengineering and RUP (Rational Unified Process/UML)[10].

The Georgia Institute of Technology presents another example, as it established the "College of Computing" in 1990. The new college was established parallel to the "College of Engineering" and the "College of Science." This indicates that the Georgia Institute of Technology places an emphasis on education in the information processing discipline. The institution is ranked high recently in the third-party university evaluation[11].

A more advanced educational content would enable students to acquire a more advanced design theory. Recently, various new concept have been introduced into software design theory. Among them are the "Spiral Model Method" and the "Agile Method." The "Spiral Model Method" provides a continual opportunity to ensure adherence to user requirements, while the "Agile Method" (agile is defined as speedy) aims for a reduction in overall process time. Lectures on these design theories are an extension of training to acquire practical software production skills.

In short, the leading school in US makes positive efforts to provide education in order to respond to technological evolution as a leader in this field.

5 History of computing education in Japan

This section traces the history of information processing education in Japan. The first electronic calculator was invented in the 1940's. The second half of the 1950's saw the expansion of academic disciplines such as control, communication, calculator, and applied mathematics. Individual universities began developing a new educational system in an attempt to respond to such changes.

In 1959, Kyoto University set up the Department of Mathematical Science and Engineering under the Faculty of Engineering. This was the beginning of a curriculum for information processing in Japan. Its establishment was aimed at "developing researchers and engineers who have a comprehensive perspective of not only common areas but also boarder areas for individual disciplines, in order to overcome difficulties of the division of disciplines into specialized subfields of science and technology and contribute to the dramatic growth of learning and industry." Kyoto University also launched the Department of Computer Science in 1970. The two departments were later merged into the Department of Informatics and Mathematical Science.

The University of Tokyo set up the Department of Counting Engineering in 1962 when it restructured the Department of Applied Physics. This was the first attempt to provide computing education at the University of Tokyo. In 1970, a research facility was established under the School of Science, which later evolved into the Department of Information Science.

In the advent of information society, there was a growing awareness of the importance of information study and education. During this period, many universities set up new departments. For example, the Faculty of Science at the Tokyo Institute of Technology opened the Department of Information Science. The University of Electro-Communications and Yamanashi University set up the Department of Computing Machinery under the Faculty of Engineering, respectively. In the 1980's, many universities set up a faculty or department of computer science in succession to respond to the call for developing more engineers with expertise in information processing. Since then, many universities have opened unique faculties and departments, including the Faculty of Business and Information Administration (Tama University, 1989) aimed at combining the discipline of social science and that of information processing, the School of Computer Science and Engineering that focuses on computer science (the University of Aizu, 1993), the Faculty of Software and Information, which is software oriented (Iwate Prefectural University, 1998).

Meanwhile, the issue of what should be taught in the context of information processing was debated as needed[5]. An examination was conducted along with the model curriculum developed by ACM, upon which each university introduced an educational curriculum that reflects the results of the examination. In recent years, J97 was developed in 1997, based on CC1991 developed in 1991[16]. This was not the result of explosive growth in Internet use or the emergence of the Web in the middle of the 1990's. Presently, Information Processing Society of Japan is developing a new model based on CC2001, with an eye to proposing a new model in the spring of 2005.

Today, a large number of students receive information processing education. According to the Association of Computing Schools in Japan [4], a total of 130 faculties and departments provide information processing programs across the country (the association has 274 members at present in 2004, including graduate schools). According to an estimate, more than 10,000 students graduate from undergraduate and postgraduate courses every year.

6 Analysis of issues

When discussing the frustration of the software industry from its viewpoint, the main complaint is that today's university education does not enable people to put theory into practice. Some may hold different views. However, it cannot be denied that in general, there is a gap between the outcome of computing education and the needs of the industry. The following is an analysis of these circumstances.

6-1 Characteristics of computing education in Japan

Despite "dramatic" technological changes in the field of information processing in recent years, universities took measures that are "gradual" to respond to the changes and the need for a new model curriculum.

Such reluctance stems from the way a new faculty or department was formed. The Faculty of Engineering consists of major industries of the mid 20th century such as Civil Engineering, Machinery, Electricity, and Chemistry. Therefore, universities "increased the enrollment limit" or "asked for a budget increase." This was mostly seen in the Department of Electrical Engineering when they set up the information-processing related departments.

In Japan, undergraduate students are allowed to belong to a laboratory when they reached their final year. This is one of the major characteristics the Faculty of Engineering is operating in Japan. Research activity based education is available for only senior students and in a guild like atmosphere after three years of preparatory education. This is probably because the Faculty of Engineering at national universities first introduced a credit system that encourages students to go into subdivided research disciplines based on the research oriented course structure. Individual laboratories that comprise an education system tend to show an interest in a specific research area only. Furthermore, research-oriented universities tend to evaluate instructors based on their research papers. This probably made it difficult for a university to make concerted efforts to implement business education or pursue newly evolved of education areas.

Reform of the education system is not simple for newly created universities with the aim of pursuing original research areas. Even after the deregulation of official requirements for the establishment of a college called the establishment of broad outline ("Taikouka" in Japanese) in 1991, newly created universities are required to adhere to the same curriculum until the first group of students graduate, and ensure that educational contents, presented to students at school entry, will be in place until their graduation. Although these requirements are essential to guarantee a right to receive education that is based on a certain philosophy, they can be a disadvantage when universities respond to technological evolution.

In general, these requirements make it difficult for a university curriculum to reflect the needs of industry.

6-2 Need to promote "engineering" education

In Japan, criteria for "skills" that must be achieved are not as clear as that in the US. Some may argue that "it does not matter if we do not meet the criteria for "skills" adopted in the US, as long as a quality education is provided." However, people who are engaged in software production are increasingly required to acquire skills that comply with the international standard, under the concept of the software as a product.

In 1998, the "agreement to recognize equivalence of accredited engineering educational programs leading to an engineering degree" which is also called the "Washington Accord" was signed. Based on the Washington Accord, JABEE (Japan Accreditation Board for Engineering Education) plans to examine and accredit programs in engineering education in line with international standards. The Committees to Develop Curriculum for Information Processing Education, a work group of Information Processing Society of Japan also believes that the introduction of the accreditation system based on third-party evaluation or international standards will bridge the gap between social needs and educational contents in the field of information processing. For that purpose, educational institutes need to strengthen software engineering education, if they place importance on the enhancement of computing education from a standpoint of the software industry. In return for the effort to strengthen software engineering education, educational institutes can build up their market competitiveness.

However, there are many obstacles to overcome for implementation of accreditation. Experts believe that under present circumstances, none of the faculties or departments of Japanese educational institutes will successfully meet the screening criteria of ABET (The Accreditation Board for Engineering and Technology) for accreditation in the field of software engineering. This is not the matter of quality of education at Japanese universities. Rather, this is attributed to the fact that there is a difference in educational systems between the US and Japan.

It is not appropriate to rely solely on accreditation as a way to enhance the contents of curriculum. Accreditation should be conducted at the final stage in a series of efforts to match educational contents to technological evolution. For that purpose, educational institutes must make systematic efforts to respond to changes, while addressing curriculum issues.

7 Recommendation to the management of undergraduate-level computing education

This section recommends measures that need to be done in order to enhance the discipline of "Software Engineering," in view of the previous discussions and present circumstances of computing education at the undergraduate level in Japan.

From the standpoint of adapting to the US style of engineer education, it is necessary to implement a third-party evaluation to uncover how Japanese universities are meeting the criteria of the existing model curriculums. In order to conduct third-party evaluation, it is essential to modify the educational content, which may not be favored by universities. Firstly, such a problem should be alleviated.

Japanese universities tend to attach a special importance to the number of theses presented at academic societies, when they evaluate the performance of instructors. Under the circumstances, it is necessary to introduce specific incentives for instructors so that they can work towards the implementation of business-oriented education. For example, the accreditation criteria of JABEE question if there is an incentive structure that recognizes the achievement of instructors, which would provide information for making an important employment decision such as that on the offer of lifetime employment. Educational institutes can take various measures such as employment policy change, introduction of fixed-term system, reexamination of retirement age, and an introduction of greater flexibility in observing the fixed number of instructors.

It is also good to provide an opportunity to instructors, who are willing to provide practical education, to participate in practical training so that they can experience software development tools that are used in the business environment. The “programming exercise” may have two completely different scopes of practice, if one provides Pascal language exercises for understanding an algorithm, and the other aims to teach how to design an input/output interface for the Web use that is based on a Java authoring tool. Private training institutions offer a variety of programs in relation to the “IT skill standard” that is highly valued in the industry. Universities can introduce new educational content, if they send instructors to these courses. In that respect, policy support would be effective.

Enhancement of teaching materials is also important. For example, a video library can be created by recording practical lectures by business people and provided through the University of the Air Foundation. It is possible to promote the use of these videos at universities. Universities can also outsource their courses. Among them are the courses that teach the basic principle and operational procedures of network facilities, and the usage of database systems. However, educational content that emphasize the efficiency or that are too business-oriented, may not seem compatible with the intrinsic values of university education. Therefore, it is preferable that certain guidelines will be developed before the introduction of measures that are aimed at facilitating implementation of the guidelines.

To reinforce the incentives for students who receive education, it would be effective to provide courses that lead to a qualification. A relationship between qualifications such as that for data processing specialist, professional engineer, and assistant professional engineer, and curriculum, or IT skill standard and curriculum should be examined first. Then, a relationship between job descriptions and examination subjects must be explained in a straightforward manner. Academic societies can play a major role in this respect.

In the meantime, the industry must treat graduates with certain qualifications well in terms of salary, depending on their qualification status. Many of the information service related companies provide extra benefits to employees who are qualified as a data processing specialist, depending on the qualification they hold. This makes it important for universities to be aware of the possibility of market principles interfering with the selection of disciplines by undergraduate students.

The present education system at engineering universities, which allows senior students to engage in a research project, is unique to Japan. It should be cherished because of its long tradition. When it comes to accreditation, due consideration must be given to this aspect of university education. On that basis, a private company and individual laboratory can introduce a year-round internship program collectively for those working on a graduate thesis. The internship program has a great advantage for the industry, because they have access to students with certain skills who could be a reliable candidate for their opening positions. If it is difficult for individual companies to implement an internship program, an industry organization should coordinate effort to develop a cooperative framework to launch the “Internship Center” or other schemes.

8 Conclusion

In the Meiji era, fledgling Japanese engineering education was modeled after Britain. After the end of World War II, it has evolved, using examples from the US system. Japanese manufacturing industry's success in the second half of the 20th century owes, in a large part, to students who studied "engineering" at universities, and who are superior in terms of quantity and quality to their overseas counterparts.

Expansion and dispersion of information processing technologies, and changes involved in terms of quantity and quality of software production represent dramatic changes that took place over the past ten years or so. Having faced such technological changes, there is a growing awareness, both nationally and internationally, that production capacity and quality of software are important for national competitiveness. Given this factor, it is imperative to increase the proportion of practical education that is leaning towards the industry and to improve the quality of education, in order to pursue the technology policy.

Notes

***1** In the context of the curriculum in Japan, the word "computing" is usually translated "Johogaku (Information Science)". This paper also uses "Joho Shori (Information Processing)" as translation for "computing" depending on the circumstances.

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