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Invited Paper

Defining Informatics across Bun-kei and Ri-kei

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Abstract: The Science Council of Japan's Committee on Informatics is currently creating a reference standard in informatics. This activity includes defining informatics for university education and for the future academic development of informatics. The most characteristic feature of the chosen definition of informatics is the desire to cover all branches of informatics across bun-kei (social sciences and humanities) and ri-kei (natural science and engineering), with the intention of unifying the field. In the present paper, the background of the activity, and the motivation and implications of the definition of informatics are presented. In particular, we discuss the importance of covering bun-kei and ri-kei for the future development of informatics and the implications of the definition on liberal arts education in universities and primary and secondary education in elementary, middle and high schools.

Keywords: informatics, informatics education, reference standard, Science Council of Japan, computational thinking

1. Introduction

Under the auspices of the Science Council of Japan (SCJ), scientists in each field of science are making a reference standard for their field, to serve in undergraduate study in universities [1]. This activity was supported by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). The reference standard in each field is expected to define the field, present the body of knowledge that the students majoring in the field will learn in an undergraduate course, and describe the kinds of competence that they are expected to gain through study of the course. The reference standard does not concretely define the curriculum of a course, but each university is supposed to design a curriculum based on its own missions and resources, and the characteristics of the students studying the course, while also referring to the standard [2]. It should also be referred to by organizations that accept students majoring in the field, and schools from which those students transfer.

The SCJ is composed of 30 committees, each corresponding to a field of science. Most committees have organized their own subcommittee to create the reference standard in the corresponding field, whereas some committees are cooperating to make a single reference standard (e.g., committees on basic biology and integrated biology have cooperated to create the reference standard in biology). Needless to say, the committee on informatics is responsible for making the reference standard in informatics. At the beginning of the 22nd term of the SCJ (from October 2011 to September 2014), the committee organized a subcommittee for discussing education in information science and technology, which I have been chairing. In the middle of the 22nd term, when the activity of the SCJ on reference standards had become prominent, it added the mission of creating the reference standard in informatics to the list of missions of the subcommittee, which is now actively working to create the reference standard, continuing into the 23rd term of the SCJ.

In general, the reference standard in each field of science should first define the field as it has evolved in the past and will evolve in the future, in relation to other fields of science. Therefore, making the reference standard in each field is a good opportunity for the field to summarize its history and suggest its vision for future progress. This should certainly be the case for young fields such as informatics.

Although the reference standards are expected to give idealistic views and visions of science, they should not be independent of actual university education, but rather, should be based on the current status of Japanese universities. This also means that they could impact the future reorganization of university education. In the case of informatics, its reference standard should also impact the education of informatics in high school and even in elementary school, because giving a well-established definition of informatics as taught in universities will make the role of education in informatics in elementary and high schools more clear.

The most characteristic feature of the definition of informatics in its reference standard, which the abovementioned subcommittee has been discussing, is that the field should be defined across both social sciences and humanities (bun-kei in Japanese), and natural science and engineering (ri-kei). This point should be emphasized, because the dichotomy between bun-kei and ri-kei is characteristic in academia and university education in Japan. The SCJ is no exception, in the sense that it is divided into three sections; one for social sciences and humanities (bun-kei) and the other two for biological sciences, and natural science and engineering (ri-kei). In contrast, informatics has origins and activities that spread across both bun-kei and ri-kei, which is considered an inherent feature of the field (**Fig. 1**).

Departments and faculties in Japanese universities are also

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classified as either bun-kei or ri-kei. Whereas departments in computer science or information engineering are classified as ri-kei, many departments and faculties related to media or communication studies, which are now considered to be important branches of informatics, are classified as bun-kei, and there are many such departments and faculties in private universities. As mentioned above, the reference standard should be based on the current status of Japanese university education.

In addition to the current status of Japanese universities, the recent development in informatics also demands a definition that spans both bun-kei and ri-kei, because an increasing number of human social activities have been the central topics of informatics in recent years, and this trend is likely to continue or become more prominent in the future. As discussed later, in its reference standard, informatics is defined as a field of science that processes information for creating new value in the world, including human societies. In this respect, informatics is considered a field that spans both bun-kei and rikei, and that provides a basis for all fields of science, in the way that mathematics serves for all fields of natural science and engineering.

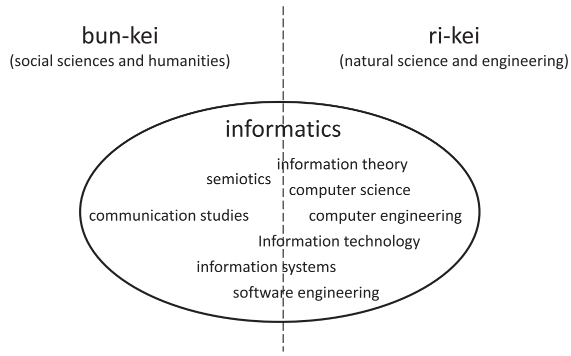

Fig. 1 Informatics across bun-kei and ri-kei. Informatics has origins and activities that spread across both bun-kei and ri-kei.

In the present paper, while describing the essence of the definition of informatics in the reference standard, I also focus on how we have produced a definition that incorporates both bun-kei and ri-kei, and what kind of impact the definition will have on research and education in informatics in Japanese universities and schools.

2. Origins and Branches of Informatics

Let us first examine the origins of informatics (**Fig. 2**). It is not obvious how far back we can go into the history of science to look for the origins of informatics. It is possible to go back as far as the ancient Greek studies on algorithms, such as the Euclidian algorithm for computing the greatest common divisor of two integers, or the Arabic studies in algorithms from which the word ‘algorithm’ itself originated. However, they are not directly linked to the current computer technology on which informatics is based. With regard to theoretical studies in informatics, formal computational models, such as lambda calculus and the Turing machine, were proposed in the 1930’s by mathematicians including Gödel, Church, and Turing, and the mathematical theory of computability was established.

In the 1940’s, the development of computers began by physicists and electrical engineers, led by von Neumann and others, and the fields of computer science and computer engineering emerged and grew rapidly. Theoretical studies concerning not only computability but also computational efficiency started to make computation with computers faster. Methods for represent-

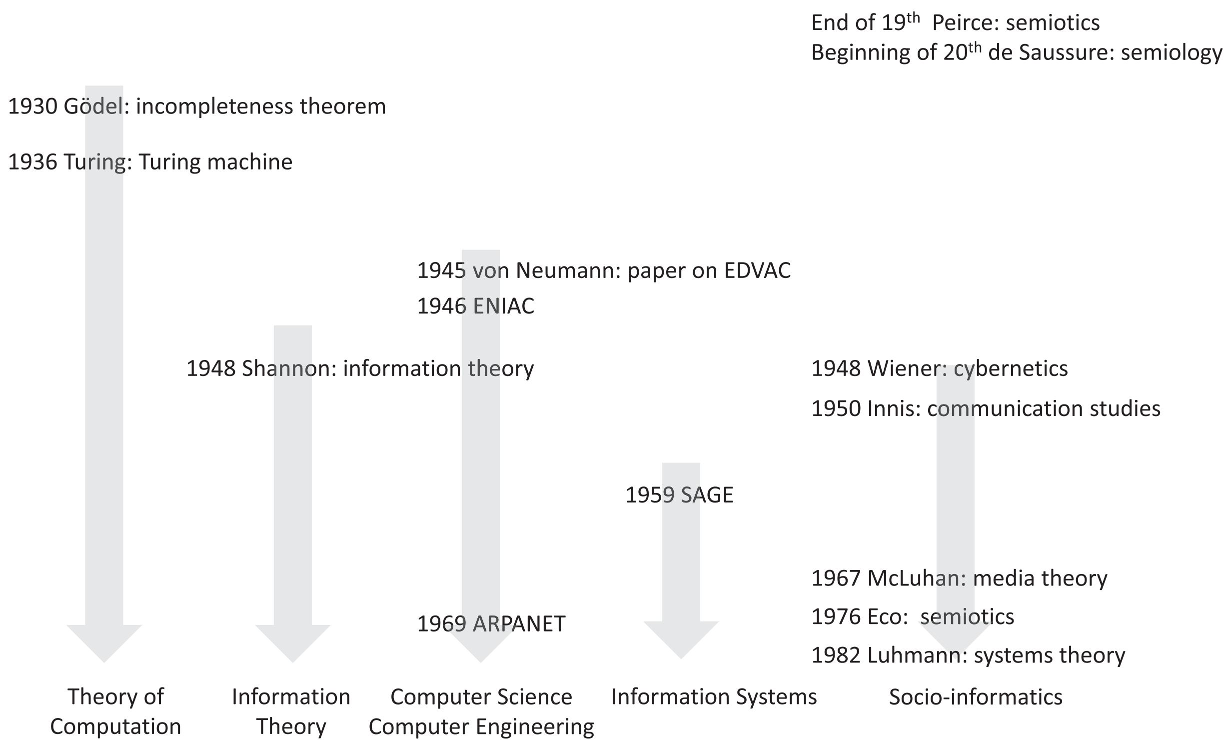

Fig. 2 Origins of informatics. Origins and current branches of informatis are shown: theory of computation, information theory, computer science and computer engineering, information systems, and socio-informatics.

ing data structures and designing algorithms progressed. Technologies for constructing computer hardware and software were actively developed. It was also in the 1940's that Shannon established the mathematical theory of communication, and thereafter the principles of transmitting and transforming information were studied.

As computers became widespread, technologies for applying computers to societies also flourished. In particular, the field of information systems (IS) evolved, in parallel with computer science and computer engineering. The body of knowledge in the field of IS is different from that of computer science, because information systems should be developed together with the organizations using them, and constructing huge information systems requires expertise for their management and maintenance.

Information systems have been developed to meet the needs of human societies, but they have also been changing human societies. In particular, information technology (IT) has enhanced media and changed the way people communicate, producing the so-called information societies. Consequently, a research field called socio-informatics emerged from related social sciences, for investigating computerized and computer-assisted communication.

It is not easy to look for the origins of socio-informatics. Communication studies by Innis [3], semiotics by Eco [4], and media theory by McLuhan [5] are all considered to be the direct ancestors of the current field of socio-informatics. But the semiology of de Saussure [6] and the semiotics of Peirce [7] cannot be ignored as foundations of these studies, and date back to the end of the 19th century.

The branches of informatics, including socio-informatics, have different origins and have been developed by different academic communities (Fig. 2). However, they are all concerned with how to process information to create value. To investigate the information societies and improve on them in the future, these branches need common principles for understanding both information processed by computers and information that appears in human communication. If the branches are all based on such common principles, they can cooperate through these principles and eventually become unified.

What then, should be the common principles that unify the branches of informatics? If it were the 1940's, cybernetics by Wiener could have been a candidate for such a common principle. As described below, it is the fundamental informatics of Nishigaki [8] that take the role of providing a unifying view of the field of informatics that spreads across both bun-kei and ri-kei.

3. Definition of Informatics and Its Body of Knowledge

The branches of informatics mentioned in the previous section not only deal with information, but also pursue the semantics and values that information defines and structures, and the order that information brings about. Even in the case of computer processing information, the semantic structures that appear among the fragments of information are of central concern. Therefore, **informatics is a field of science that investigates principles and technologies for defining semantics, creating value, and giving order to the world, by processing information**. The principles and technologies for processing information include those of creation, generation, collection, representation, recording, recognition, analysis, transformation, and transmission. From this point forward, I use the term ‘process’ to denote all of these acts of manipulating information.

Based on the origins of the branches of informatics mentioned above, and the current academic societies and organizations for university education, the reference standard in informatics classifies the body of knowledge into the following five sections:

A) General principles of information;
B) Principles of information processing by computers;
C) Technologies for constructing computers that process information;
D) Understanding humans and societies that process information; and
E) Technologies and organizations for constructing and operating systems that process information in societies.

Section A has the role of giving a unifying view of the branches of informatics that spread across bun-kei and ri-kei, and is based on the fundamental informatics of Nishigaki [8], which follows the origins of socio-informatics mentioned above (e.g., semiology, semiotics, communication studies, media theory), and is also strongly influenced by the concept of autopoiesis by Maturana and Varela [11] and its application to sociology by Luhmann [10]. It is worth noting that to write this section of the reference standard, the subcommittee invited Nishigaki to join them as a member.

Luhmann's systems theory [10] is currently well accepted in socio-informatics. According to the theory, a human society consists of communications as its components, and is an autopoietic system in the sense that it is constantly reproduced by producing its own components. Nishigaki's fundamental informatics [8] introduces the existence of an observer into autopoiesis, and well explains the component-composite hierarchy of autopoietic systems. In the hierarchy, while component systems remain autopoietic, they work as allopoietic systems inside a composite system from the point of an observer. This makes it possible to treat both individuals and societies as autopoietic systems. Extending the hierarchy to include computers as allopoietic systems, it becomes natural to classify information into three categories: mechanical, social, and life, in which life information is the most fundamental form of information shared by all living creatures that are autopoietic; social information is communicated in societies which are hierarchical autopoietic systems; and mechanical information is processed by computers that are allopoietic systems. This classification corresponds to that of signs by Pierce (i.e., icon, index and symbol), and can also be applied to classify semantics and communication. Because this unifying view of the various types of information should also serve to unify the various branches of informatics, this section is located at the beginning of the reference standard.

Section B covers the foundation of computer science and computer engineering, and includes the theory of computation, the theory of communication, and the theory of information. It covers the foundational part of computer science (CS) in the Computing Curricula of the Institute of Electrical and Electronics Engineers/Association for Computing Machinery (IEEE/ACM) [12].

Section C covers the technologies for designing and constructing computer systems and networks. It includes the majority of CS and all of computer engineering (CE) in the Computing Curricula of the IEEE/ACM.

Section D includes media and communication studies, and corresponds to the current field of socio-informatics. Unlike the Computing Curricula, there seems to be no internationally accepted standard for socio-informatics. Therefore, the subcommittee is required to define socio-informatics from scratch. However, the committee on informatics as a whole belongs to the third section of the SCJ (i.e., the section for natural science and engineering). Therefore, to create the reference standard, the subcommittee invited Ito, the president of the Society of Socio-Informatics in Japan [13], to become a member, and asked him to summarize the items belonging to this section.

Section E is related to information systems, and corresponds to IT, IS and SE in the Computing Curricula. It not only includes technologies for constructing information systems, but also includes principles for organizing human systems, including those on law and management. It is worth noting that programming and software engineering are also placed in this section. In addition, it includes technologies for human-computer interfaces for constructing information systems, and the related understanding of humans who use information systems.

The five sections reflect the origins of informatics and the current status of related academic communities. Therefore, there are overlaps among sections, and some items in one section may be suitable for another section. For example, the study of cognitive aspects of humans belongs to E as a basis for the human-computer interface, but could more naturally belong to D. However, the academic communities related to D originated from sociology, and are rather independent from cognitive science. Despite the compromises mentioned above, covering the various studies related to informatics should be the starting point for unifying the field for future development.

4. Domain Informatics and Informatics as a Meta-science

As previously described, informatics has diverse origins. In addition, there are hundreds of fields of applied informatics (also called domain informatics). These facets make it extremely difficult to define what informatics is. In the subcommittee, including socio-informatics in the reference standard prompted discussions about including more application fields, such as bio-informatics, medical informatics and mechano-informatics. In this respect, it should be emphasized that those fields of domain informatics not only include fields in ri-kei but also many fields in bun-kei such as management informatics (study of management information), econo-informatics, policy informatics, law informatics, literature informatics, library informatics (library and information science), and educational informatics. They even include fields in fine arts and music such as design informatics, music informatics, and entertainment informatics.

During these discussions of the subcommittee, it was claimed that it was difficult and unrealistic for undergraduate courses in universities to include those application fields (domain informatics), and it was more appropriate to define and teach the core of informatics.

Another viewpoint was recently proposed by Yamazaki [14] in regard to the education of informatics in elementary and high school. The author regards informatics as a meta-science like mathematics, statistics, or philosophy. While mathematics is mainly a meta-science for natural science, engineering, and a few social sciences including economics, and statistics is mainly a meta-science for the sciences dealing with data, informatics is considered to be a meta-science for all fields of science, including social sciences and humanities, because they all have aspects of information. If informatics is considered to be a meta-science, the boundary between informatics and domain informatics becomes clear. As a meta-science, informatics provides general principles of information to all fields of science, and it takes feedback from those fields to inductively extract new principles about information (**Fig. 3**).

As mentioned above, the fields of domain informatics spread over both bun-kei and ri-kei. This means that informatics as a meta-science should also include general principles of both bun-kei and ri-kei to create (possibly new) domain informatics both in bun-kei and ri-kei. Since the main players in any field of bun-kei are humans and human societies, informatics should include general principles on how humans and human societies generate information, communicate information and create values from information. This is exactly the reason why socio-informatics is included in the core of informatics, i.e., informatics as a meta-science, and those general principles are defined in Section D of the reference standard.

As discussed in the next section, the fact that informatics is taught or is expected to be taught in primary and secondary education is another reason why informatics is classified as a meta-science. Notice that most hours in primary education are spent in reading, writing, and arithmetic. From an academic point of view, these skills are all investigated in meta-sciences. As mentioned before, mathematics is a typical meta-science, and it is taught as arithmetic in primary education. Reading and writing are investigated in the field of linguistics, which can also be considered as a typical meta-science. Since IT can be taught in primary education as a combination and extension of reading, writing and

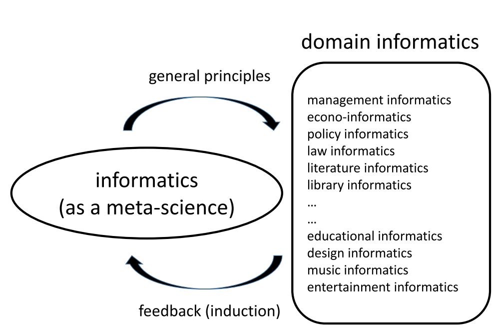

Fig. 3 Informatics as a meta-science. The core of informatics provides general principles of information to domain informatics, and takes feedback from them.

arithmetic, informatics is naturally classified as a meta-science.

5. The Impact of Informatics across Bun-kei and Ri-kei

As discussed above, informatics is a field of science for creating value from information. Toward this goal, branches of informatics should be unified, and a consistent curriculum for university education in informatics should be designed. This reference standard should be a starting point for such activities.

Education in informatics at university is expected to be based on this reference standard. Although current departments and faculties in Japanese universities are based on one or a few of the origins of informatics and do not cover all of the disciplines in the reference standard, when each university designs its curriculum for informatics, based on its mission, its resources and the characteristics of its students, it should make its best effort to realize the idealistic vision described in the standard. Each university or department may focus on some part of the standard, but all of the students majoring in informatics should be given the overall view of informatics as described in the standard.

Informatics is a basis for all fields of science, as mathematics is a basis for natural science and engineering. Consequently, informatics is widely taught in a course that is part of liberal arts education in universities; such a course is often called general informatics. The reference standard as defined above can also serve for designing a curriculum for general informatics. Note that liberal arts education is closely related to the meta-sciences, because they are the foundations of all fields of science and it is appropriate to teach them in liberal arts education.

It is widely recognized that Japan ranks low among developed countries in applying IT to solve problems in societies, while Japan ranks high in IT infrastructures such as optical fiber network. The reason of Japan's low rank in application of IT is often attributed to the fact that managers in companies or governments lack knowledge and skill in IT, and most such managers graduated from a department in bun-kei. It should be emphasized here that general informatics is taught to students in both bun-kei and ri-kei. Enriching education in general informatics is therefore expected to solve the above problem.

In Japan, a new course in informatics was introduced to high school education in 2003, and its curriculum was revised in 2013 [15]. As of 2015, the course is compulsory and consists of two subjects: 'the science of information' and 'society and information'. Students are required to take one or both subjects. They both cover the technological and social aspects of information, although they differ in their focus, and all of the students are expected to learn informatics from both aspects. The reference standard also reflects the direction of high school education in informatics, i.e., it covers both aspects of bun-kei and ri-kei.

Because mathematics is established as a field of science and gives a basis to education in mathematics in school, the reference standard in informatics should serve to give a basis for education in informatics in high school. Note that it is currently under consideration to introduce education in informatics to junior high schools and even to elementary schools. For example, the committee on industrial competitiveness (sangyo kyoso ryoku kaigi) led by the prime minister has suggested to strengthen eductation on IT including programming in compulsory education.

On the other hand, the SCJ requires that the reference standard of each field of science define generic skills that are acquired by learning the field at university, in addition to the skills that are specialized to the field [1]. Generic skills may be acquired in all fields of higher education, but Yamazaki claims that education in a meta-science should directly serve to grow generic skills [14]. It is obvious that generic skills related to information processing, such as problem finding, modeling and problem solving, are gained through education in informatics, and they are currently classified as computational thinking [16]. In the subcommittee, it is currently discussed how more kinds of generic skills, such as leadership, communication and presentation ability, and ability to create new services and values, can be gained through education in informatics.

In summary, the reference standard in informatics is expected to give a backbone to education in informatics from elementary school to university level. Through general informatics, every schoolteacher can also gain basic knowledge and competence in informatics. In this sense, a good cycle for teaching informatics will be established.

From an academic point of view, as discussed already, the reference standard is a starting point for a unified field of informatics. In particular, the role of socio-informatics is important in providing disciplines for creating value from information. So far, socio-informatics is mainly concerned with observing phenomena in societies influenced by IT. In the future, it is expected to provide disciplines and methods to design societies by cooperating with those branches of informatics including computer science and information systems.

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