How to Educate Students to be Future Systems Engineers?

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Abstract: Companies require new employees who can create a business chance and utilise information technology. For future systems engineers we have to teach students fundamental methods of systems engineering for development of information system or systems thinking. Teachers need an information environment and useful application software for students to freely use computers for their interesting field and chances to cultivate their abilities. As a result these environments strengthen their insights into issues, users' requirements and selection of software in views of problem solving and raise the level of their abilities dealing with information technology.

1. INTRODUCTION

Now in the era of information technology (IT), many computers are used in various fields in business. Companies are continuing to invest computer powers in their offices and works to improve their efficiency in management. For these investments, many systems engineers are required not only in information companies, but also in other types of companies. In Japan, many graduates get their jobs in the companies related to the IT industries and also in information processing sections in the conventional companies not related to the IT industries. Companies eagerly require new employees who can utilise computers. This implies that undergraduate

students should have acquired some abilities of systems engineering or systems thinking in order to get jobs with companies.

2. RESPONDING TO REQUIREMENTS FOR NEW EMPLOYEES IN JAPAN

In education in universities in Japan, especially in technological faculty, computer literacy is a graduation requirement. In almost all faculties of engineering in universities and colleges in Japan, students can use fundamental functions of personal computers as tools for preparing papers, presentations, emails and Internet surfing.

In our Department of Management Science, Faculty of Engineering, Science University of Tokyo, the main objectives of teaching are: (1) computer, (2) technologies for utilising a computer, such as mathematics for analysis, modelling and simulation, and (3) management in social, economical and industrial fields. Computer education in our department focuses on teaching about 100 students in each grade of the first and second undergraduate the fundamental knowledge of computer: literacy, how to use Internet and a computer language. In the fourth grade and the second grade in a Master course, 80 percent of students apply for jobs with IT industries or IT related sections in companies and as systems engineers.

Social or company requirements for abilities of new employees are (1) creation of a business chance for a company, and (2) utilisation of IT in various fields of management. The abilities are cultivated by applying so-called systems thinking to a target issue. Systems thinking always grasps the target issue in a normative fashion or in top-down viewpoints. In other words companies require of employees some of the abilities of systems engineers. The roles of systems engineers are to set up the objectives of the target issue, to discover problems against the objectives and to apply IT to various fields of management. Systems thinking are key abilities for every systems engineer. Fundamental education of systems engineering is vital for students aiming to be future systems engineers.

In our department, we intend to teach students how to utilise computers. In the ways of computer utilisation, there are two directions: enhancement of application technology and adapting application software to user's requirements. The role of systems engineer is important for the latter case. In introducing IT, it is difficult for company managers as users to make clear their requirements for IT, compared with an introduction of a manufacturing machine in a plant, because a manager cannot estimate the performance per cost of IT. To make clear what types of hardware and software should be introduced in the site is one of the main roles of systems engineer.

Conventionally Japanese education focused on teaching “How to do ---?” but society outside of schools requires employees to think about “What to do ---?”

For developing future systems engineers we have to teach our students methods of system development and systems thinking, especially methods of requirement analysis: declaring target issues, proposing alternatives of ideas solving the issues and their evaluation. In a process of system development, systems thinking plays a very important role in selecting one of alternatives or in decision-making.

3. ENFORCEMENT OF ICT WITH SYSTEMS ENGINEERING IN EDUCATION AND TRAINING

Among lectures related to ICT (information and communication technologies), I give two lectures for the third grade students as shown in Table 1. One is ‘information system engineering’ and the other is ‘theory of simulation’ (Ohnari 1998).

Table 1. Education for 3rd & 4th Grade Students

3 rd grade				
	April	July	Sept	Jan
Lecturer	<u>Information System Engineering</u>		<u>Theory of Simulation</u>	
	100 students		50 students	
Seminar	<u>Training of Systems Engineering</u>		<u>Training of Modelling</u>	
4 th grade				
	April	July	Sept	Jan
Tutorial	<u>Research for Graduation Theme</u>			
	5 to 14 students			
Students	<u>Job-hunting.</u>			

In the lecture of information system engineering, I teach informatics combining with essence of systems engineering (Ohnari 1994). Systems engineering teach us a normative thinking, in other words, top-down thinking. System is defined as that it has objectives and contains many elements, and elements are organically combined each other. A system is usually too complex to understand because there are many elements in it. So relations of elements should be visually described in normative fashion by using an objective tree for example. In my classroom I teach normative expression, objective trees, evaluation and selection of alternatives by use of relevance matrix. I assign students some homework to find a problem occurring for each student, to make clear the problem with the aid of some tools used in systems engineering, to search alternative solutions as many as

possible, to evaluate the alternatives by the relevance matrix, and to select the best one among the alternatives or rank them. Students are also requested to write their thinking processes visually. Lastly each student has to compare the selected result with their intuitive hypothesis. If a result differs from the intuitive evaluation, the student is asked to review the difference between the result and their hypothesis or intuition. I give students advice on how to make much of personal intuition, by introducing an episode of intuition power which professional players of GO or SYOGI have. In the course of lecture of Shannon's information theory, I ask students to draw the theory visually in order to learn the comprehensiveness of drawings at a glance.

A result of the questionnaire taken from students reviewing the lecture of systems engineering reveals its effectiveness for them as shown in Table 2.

Table 2. Results of Questionnaire (20 students)

Q1: What kinds of impression do you have in education of systems engineering?			
	Yes	Medium	No
Fresh, stimulative	7	3	
Useful, may be useful	10		1
Hard to understand	5		
Not able to understand	2		
Q2: Systematic or visual expression of issue around you			
	Yes	Medium	No
Interesting exercise	8	1	
Enjoyed	2	2	2
Hard to describe	14	1	
Useful, may be useful	5		
Not able to understand	1		
Q3: Systematic or visual expression			
	Yes	Medium	No
Interesting exercise	7		1
Enjoyed	1	3	3
Hard to describe	14	1	
Useful, may be useful	13		1
Not able to understand		1	

In the lecture of theory of simulation, I lay emphasis on how to build a model from gathered data by the method of multiple regression analysis that is selected as the simplest modelling method (Ohnari 1997). For preparing to teach regression analysis, the sweep-out method for solving simultaneous equations is demonstrated in order to show how to implement it on a spreadsheet software Excel in personal computer. Every student implements an example of the sweep-out method for solving two-elements-simultaneous linear equations on each personal computer. While in implementation, a

value in cell is obtained by dividing some value by a value of pivot cell. In this division, conversion of pivot cell address in a relative expression (e.g. A1) to in an absolute expression (\$A\$1) is an important point to learn. After mastering Excel and implementation of the sweep-out method, students are guided to build up a procedure of a multiple regression analysis by applying the sweep-out method to a given set of data on each personal computer. This guidance is aided by a sheet of computer printout, which shows calculation process and results of multiple regression analysis for the given data of two independent variables and a dependent variable.

Two types of homework are given to students: compulsory problem and free problem. The compulsory problem offers students a problem of regression analysis with a set of data. Through this problem, students learn how to draw scatter map, and slopes intuitively in it, and select independent variables by the step-wise regression method.

For the free problem, students have to gather data and analyse it and build a model by the regression analysis. In the course of modelling some students encounter the problem of multicollinearity. When some students meet with it, I explain its reason.

4. HOW TO BUILD AN INFORMATION SYSTEM: A KEY ISSUE OF SYSTEMS ENGINEER EDUCATION

For training future systems engineers, it is effective to encourage them to build a small information system by themselves from the start of selecting and finding their themes to the final step of evaluating the outcomes of their developments. Building even a small information system inevitably contains an engineering process as shown in Figure 1, including many problems which systems engineers has to deal with.

Figure 1. Flow of Information System Development

In Japan, many students in the forth grade in the faculty of engineering are assigned to a research laboratory and have a chance to receive a graduation tutorial from their teacher for making a graduation thesis. Each teacher has a speciality in technology or academic field. Many teachers naturally guide each student to select a theme among their specialities for a graduation thesis or give them a concrete theme.

As I have experienced in building models in various fields when I engaged in research laboratories of a manufacturing company, I have not given students any concrete theme. I intend to give each student a chance to find a theme by themselves. Finding a theme has various risks and issues for students to learn and experience. Every student in my laboratory has to select a field and find an issue with which they can deal as a theme for the graduation thesis. Some students in my laboratory find analysis problems as their themes. For preparing graduation theses in the forth grade, the third grade students are trained in each laboratory beforehand.

5. TRAINING STUDENTS FOR BUILDING AN INFORMATION OR ANALYSIS SYSTEM

For preparing the themes for graduation theses, each teacher in our department gives seminars to the future applicants to their laboratory among the third grade students. I also open two seminars sequentially in a year for them: one for training them how to practice systems engineering in the preceding term and the other for reinforcing the abilities of them in modelling in the last term.

For training a group of the third grade students who are interested in systems engineering, I give them chances to practice requirement analysis because it is important for systems engineer to find issue and problem. In order to solve the issue, systems engineer usually analyse user's

requirements and propose a configuration of hardware and software, algorithms and tools for solving the problem.

Each student is required to find an issue of a personal matter and consider it as a problem of system construction. After doing this problem for homework, each student presents a report including their theme, objectives, issue, alternatives of solving, selection of the best solution, and evaluation of his or her thinking process.

I ask them, in the meantime, to describe some specifications of their handicrafts, handiwork, dishes and so on, which they made in their younger ages. These days many students have rare chance to build something by themselves, so it is important to teach them the process of design and manufacturing in a primitive form.

For training students in modelling and simulation techniques, I give students an exercise of making a polynomial model of t values with the significant level of 0.05 by using the data shown in t distribution table attached to a book of statistics with the aid of regression analysis. Another modelling exercise is to generate a set of data by using a cubic curve and adding random number, to select several subsets of the data, and to make several types of polynomial models depending on the subset. Students understand the effects of data selection by this exercise.

In order to build up an information system, builders use several types of software. Students who are going to build some computer system have to select some software for use beforehand. So I give them advice of acquiring the knowledge of application software needed for the system construction. Students in my laboratory have utilised several types of application software such as Visual basic or VBA for making graphical user interface, relational database management system Access for unitary management of data, animation software Macromedia director and Poser 3, and statistical software packages for the regression analysis and economical time-series analysis.

6. GRADUATION TUTORIAL AND THESIS

The fourth grade students attached to my laboratory have to find their themes for graduation theses. Finding a theme means to choose a field and select some methodology to handle the theme in a computer. It takes many months to determine concrete themes, partly because students are very busy for applying for jobs or the entrance examination of master grade from spring to early summer. During job hunting, students learn many types of company activities and social problems including etiquette. After the summer vacation, students begin to think about their graduation theses in

earnest. I give advice to students in my laboratory to select an acquainted field such as circle activities in university, part-time jobs, family business or jobs of parents, and hobbies in families. If a student knows well the field, they can play both roles of user and maker of an application system in computer in finding issues and problems, gathering and devising many alternatives of solutions.

During eight years I have been engaged in the university as a professor, several dozen of students graduated from my laboratory. Almost all students selected their graduation thesis by themselves.

Typical fields of graduation theses are sports of baseball, golf, ski, snowboard, boat, yacht and scuba diving, culture lessons of KIMONO dressing, tee ceremony and tole painting, part-time jobs of pizza delivery shop, Japanese pub, KARAOKE shop, VCR rental shop and hotel cloakroom, and small companies managed by parents of resort hotel, clothing shop, fruit & vegetable retailer and connector manufacturer.

Typical theses are listed in Table 3 by categorised them by themes.

Table 3. Typical Graduation Theses

Sports training

Development of educational software for alpine ski technique (Odaka and Ohnari 1999)

Development of pitching behaviour simulator for baseball training (Mori et al. 2001)

Prototyping of self-learning system of strategy and tactics in yacht races

Development of scuba diving training system

Development of learning system of golf putting with the aid of animation

Supporting of culture lesson

Development of learning system how to dress KIMONO (Kawabe and Ohnari 1999)

Development of system for communing with tee ceremony

Development of educational software for tole painting technique (Yuguchi and Ohnari 2001)

Analysing some business segments of companies students were hired as part-timers

Analysis of posting effects on pizza delivery shop depending on the delivery areas

Construction of models for prediction of sales amounts and required man-hour in Japanese pub by economical time-series analysis

Prediction of the number of baggage to be kept in the custody of floor cloakroom in a hotel

Analysis and estimation of sale amounts in KARAOKE shop by economical time-series analysis

Supporting small companies managed by one of their parents

Management Improvement of a small size overseas resort hotel with the aid of information technologies

Construction of an Intranet preparing for e-business in a small-size manufacturer of electric connectors

Development of system for sending and receiving orders in fruit and vegetable retailer

Sales support systems for small clothing shops

7. EVALUATION

Results of selecting an acquainted field for each student reveal that: (1) a student can decide the ways in their research alone, because they have a measure of value in the selected field. Therefore they can tackle their issues without doubt, (2) in the themes of analysis problem, if a student selects a theme related to their part-time job, they can easily gather data in their working site and devise a new method of gathering or arrangement of field data, (3) in the case of selecting a tool, they can select an appropriate tool to their issue, because they can decide or review the tool in view of a critic or user. Therefore they can concentrate on the theme by using the tool with confidence.

In the course of research for graduation, although various unknown matters burden students, they challenge and gradually overcome these matters, gain new knowledge, and cultivate their abilities. Many graduates of my laboratory express their impression that my teaching and training process are effectiveness when they joined in companies and engaged in systems engineering. They say that education of systems engineering and thinking is useful especially in information companies. I myself evaluate that my teaching philosophy and training practices satisfy the requirements of today's company.

8. CONCLUSION

After being engaged in laboratories of a manufacturing company in Japan, I have been a professor teaching information system engineering and simulation engineering. In the classrooms and seminars, I tried to guide students to think and build something they have interested in.

Education of the computer is usually aimed to make students able to use computers up to a limited level. The theme of this conference is "Computers in Education". I think this theme urges teachers to create an environment to students who freely use computers for their interesting field and chances to cultivate their abilities of finding issues and solving problems by computers. For these purposes it is important to maintain computer environments and to prepare useful application software for their use. As a result these environments strengthen their insights into issues, user's requirements and selection of software in views of problem solving and raise the level of their abilities for IT.

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BIOGRAPHY

Mikihiko Ohnari has experience of system developments especially in installing control computers into industrial or social plants, such as rolling mill plants, municipal water supply plants. In these system developments in Hitachi, Ltd., he encountered issues in extracting users' requirement and describing requirement specification, verification and validation. Now he is Professor of Science at the University of Tokyo and teaching students who will be future system engineers through lectures, such as information systems, and the theory of simulation.