

# Introductory and Engineering Ethics Education for Engineering Students in Japan\*

HIROSHI IINO

Kanazawa Institute of Technology, 7-1 Ohgigaoka Nanoichi Ishikawa, 921-8501, Japan.

E-mail: h\_iino@neptune.kanazawa-it.ac.jp

*In 1996, the author developed a new introductory subject for freshmen called 'Society and Engineers', which is suited to the special educational situation in Japan. To date approximately three thousand five hundred students have taken this course. The goal of that course is for students to learn for themselves who engineers are and the world context for engineering work before studying engineering ethics. It uses three cases of accidents in nuclear energy development in Japan. Before 1999, few technical institutes provided engineering ethics education, but the new accreditation requirements for education set forth in 2000, prompted about twenty technical institutes to offer engineering ethics that year, and its influence on engineering students is increasing rapidly. A workshop and symposium were held and the textbooks and case studies for the education were developed and published. The influence and importance of corporate social responsibility for engineers' behavior and the needs for education of managers are emphasized.*

## INTRODUCTION

AFTER WORLD WAR II, the work of Japanese engineers was largely responsible for making Japan the No. 2 economy in the world. Until forty years ago, Japan had no major accidents or scandals concerning engineering work, except possibly some environmental pollution scandals, such as that surrounding Minamata disease [1]. The Japanese engineers inherited traditional values of craftsmanship and worked for clear targets such as saving human lives and improving economy and environmental conditions.

During this period, a fraction of engineering students had learned ethics as an elective in liberal arts program at universities. As the welfare in Japan improved, the central values of engineering were obscured by an overriding concern with making money.

Eight years ago, when the author started the class here described, only a few attempts to teach engineering ethics had been made in Japan.

## DEVELOPMENT OF 'SOCIETY AND ENGINEERS' CLASS

The author has worked in industry for thirty-seven years as an engineer and management and, in 1995, was asked by Kanazawa Institute of Technology to develop an introductory subject for freshmen that would include engineering ethics. Having known several accidents or mishaps

in which engineers might be involved, and having perceived deterioration of graduates' quality level in Japan, the author thought the subject very important.

After a short study the author realized that freshmen do not know:

- who engineers are;
- what engineers do in society;
- what is happening in a rapidly changing world.

Some were enrolled simply based on their 'deviation value' (achievement test score) rather than because they were motivated to become engineers. Prep schools analyze statistically test performance of students to supply each student with a deviation value. Being given this value, the student chooses a university to meet it.

It became common during the period of economic expansion for parents to support their children financially up to their graduation from university. Because of this and the good job market for graduates that prevailed for years, students had not studied hard but enjoyed youthful pursuits prior to the current economic stagnation. Accordingly, only a small fraction of freshmen in Japan think seriously about their own lives and try to establish 'self' as in western countries. They may start thinking seriously about these issues only at the time of their enrollment in higher education. After the WW, discussion of 'values' became taboo and no Japanese, young and old, were willing to discuss it openly.

Establishment of 'self' and discussion of 'values' are two most important prerequisites for autonomy of judgment in engineering ethics, however.

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Compared with the concept of the self that is prevalent in the USA, the Japanese notion generally has depended more on the relationships with other people and organizations [2].

To better meet the needs of Japanese students, the author developed a new course meeting for 3 hours per week for ten weeks, named 'Society and Engineers'. About 3,500 students have finished the class in six years. Course topics include:

- The definition of an engineer (taking ABET's EC2000 [3] as a target for engineering graduates).
- The engineering knowledge and skills needed in a knowledge-based economy.
- Time management.
- Studying engineering and working as an engineer.
- Social environments in the world and Japan now and in the future.
- Global environmental problems and role of engineers.
- The role and responsibility of manager and managing organizations in Society.
- Research and development (R&D) and bringing a new product to market.
- Quality control and quality assurance, ISO 9000 (the ISO's procedures applied to quality control) of each company, ISO 14000 (ISO's procedures applied to environmental control of each process of a company), patents, patent law and anti-monopoly law.
- Three case studies in nuclear energy development in Japan.
- Influence and conflict encountered in engineering work.
- Codes of Ethics for engineers in Japan and USA.
- Professional autonomy in ethical judgment and maturation of the self.
- Starting up one's own company.
- Engineers and engineering students in other countries.
- Life plan for engineers and professional development.

Students have three writing assignments using Microsoft Word format:

1. The first is to read a newspaper and submit ten weekly reports each containing ten topics of the student's choice selected from events on society, economy, politics and industry. Each topic must be neatly summarized in one typed line in Japanese. Also, two words in the newspaper that the student did not know. Students are to explain the words in three or four lines in Japanese. This, together with the explanation in class of above-mentioned fifth topic, social environments in Japan and the rest of the world in the past or future, helps them understand changing societies by themselves in their own ways. This also teaches students how to read newspapers, summarize the contents in a short

sentence, express their own opinions, and discuss societal issues with one another.

2. Second assignment is to submit a two-page report on what they think of their own life and their future after reading a book on positive thinking.
3. Last assignment is to submit a three-page report on what they think about society, the world, the Japanese, and themselves. The students write the report in their own words so that the author can assess and confirm the development of their thinking about the world and engineering ethics. These reports also showed a dramatic improvement in their motivation to study at the technical institute.

### TEXT BOOKS

In 1996, there was no good textbook in Japan for the purpose. So, in 1997, the author created a textbook from the class handouts. It was published in 1998 as 'Becoming and Being an Engineer' [4] and covers all 16 items already described. Revisions of the book have appeared every other year, with the fourth edition appearing in 2004. It has been used at more than fourteen national and private engineering schools in Japan and as a guidebook for working engineers in industry who have not had any engineering ethics education throughout their careers.

### RECENT ENGINEERING ETHICS EDUCATION IN JAPAN

In response to the need of world-wide qualification of engineering graduates, JABEE, Japan Accreditation Board of Engineering Education, was established in 1999 and made a list of common engineering criteria for the outcome assessment which requires engineering ethics education, among other things [5]. The author encountered the following problems, however:

- Lack of knowledge of the content of engineering ethics education. Even though some information was available from USA, modifications were necessary to accommodate differences in culture, traditions, and way of thinking [6].
- Lack of good textbooks in Japanese.
- Lack of instructors in engineering ethics.

The first workshop on engineering ethics with seventy-three academics, engineers and representatives from engineering societies was held on November 27 and 28, 2000 near Tokyo. Since then one conference on engineering ethics was held in March, 2001 in Nagoya and several Japanese textbooks were published in 2001 and four American textbooks have been translated in Japanese since 1998 [7-9]. Although the diffusion of engineering ethics education into engineering education was very limited and the number of

technical institutes offering an engineering ethics class was only about twenty in 2000, that situation is changing rapidly since JABEE made engineering ethics education compulsory in accreditation.

### CASES IN NUCLEAR ENERGY DEVELOPMENT

In Japan, real causes of accidents had not been well analyzed until recently, partly because its purpose was mostly to find the culprits rather than to prevent the same error or mistake. The Japanese legal system does not have plea-bargaining with judicial immunity that facilitates investigations of causes of accidents or mishaps.

The author used the following three accidents in the class as cases since they were known by the students, fairly well analyzed, and published by the government.

#### *Case 1: 1995 fire at Monju prototype fast breeder reactor*

In 1995, while the MONJU prototype breeder reactor was being tested at 40% power, non-radioactive sodium of about 640 kg leaked from secondary heat exchanger piping through a broken thermometer sheath. The sodium ignited on contact with the air. No injuries or radiation exposure occurred because the secondary heat exchanger transfers heat from the primary heat exchanger, which takes the heat out of the core of the reactor to the steam generators for power [10].

The break in the sheath occurred because of a design error, which resulted in a sharp cut edge that caused stress concentration; there was neglect of vibration analysis of the sheath parallel to the sodium flow.

Initial cover up evidence—specifically denial of the existence of videotapes made and subsequent editing of those videotapes combined with delay in informing neighbors of the accident—ignited a public protest against the people engaged in the nuclear power development project.

This example illustrates that a small design mistake in a cheap component costing less than \$1,000 can cause a major accident. The severe loss of public trust, mainly from the cover up, resulted in delaying the nine billion dollar projects for more than nine years, although the government wants to resume the project as soon as possible.

#### *Case 2: Fire and explosion at bituminization demonstration facility in 1997*

The facility treated a low radioactive nuclear waste water by mixing it with molten bitumen and evaporating water in a steam heated extruder at 180°C and pouring the mix into steel drums to cool down. Since the waste water contained sodium nitrate, a strong oxidant at high temperature, bitumen and some other chemicals susceptible to oxidation, the possibility of an oxidation reaction

had been considered when the operation was started nineteen years earlier.

An experiment to reduce a flow rate by 10% and then by 20% was planned and carried out. The reduction of flow rate caused an increase of the mix temperature due to both prolonged steam heating and heat dissipation by rotating screws at the extruder and enhanced oxidation reaction by sodium nitrate in the extruder and consequently within the drums.

The subcontractors' operators observed the lower viscosity of the mixture, an indication of higher temperature, but the thermometer at the exit of the extruder had been out of order for years, so they did not detect the danger until they saw pillars of flame on the cooling drums. To extinguish the fire the operators splashed water from sprinklers for one minute and reported the fire to the engineers. The engineers may have been busy trying to contain the radioactive materials within the building, but none of the engineers responsible for the operation came to the site of the fire until an explosion occurred 10 hours later. A small amount of radioactive materials leaked out of the building [11]. Tens of workers had been scheduled to enter the building 40 minutes after the explosion. Fortunately, no one was injured in the accident.

Engineers could have foreseen the explosion if they had understood what caused the original fire and time necessary to cool down the oxidation reaction within the drums. This case can be used to show the students the need for care, competence, and foresight in discharging engineering responsibility.

Both operations were conducted and managed by PNC, Power Reactor and Nuclear Fuel Development Corp, the government controlled organization, which in response to public protest was later reorganized into JNC, Japan Nuclear Cycle Development Corp.

When asked if the atomic energy is absolutely safe, those engaged in nuclear development had no other answer than 'yes'. In 2001 after long discussion including other people, engineers were able to admit to the public that no technology is absolutely safe. This sounds antagonistic to technology, but it is a truth all engineers understand and one that will help people understand technology and brings out the importance of the responsibility of engineers.

These two accidents also illustrate the following four points:

1. Good machines and technology had been developed by nuclear engineers who took proper action in their scale-up designs in accordance with their experience of mishaps at the smaller machines. However, as more than 15 years had passed without any accident and these engineers left the floor, a new generation of inexperienced engineers had taken over. In the absence of trouble, they grew overconfident in the safety

of their technology. They became arrogant because they lacked their predecessors' wisdom and experience of accidents at other facilities.

2. Government-supported R&D is sometimes necessary but tends to become bureaucratic with time and ignore the original target. Engineers sometimes become the kind of managers who do not know the facts on the floor yet want to do some experiment for their work.
3. In the case of the 1997 fire, the experimental design neglected the safety precaution for the subcontractor's operators and of operation itself.
4. Another lesson from the 1997 case is that an accident is more likely when those involved think the operation less important and less in need of care.

The next accident also involves a minor mistake, but one that resulted in a catastrophe.

#### *Case 3: Criticality accident at JCO in 1999*

In 1999, a criticality accident at JCO [12] astonished the Japanese and the rest of the world. Three workers were refining an 18.8% enriched uranyl nitrate solution in a small facility at Tokaimura, 140 kilometers north of Tokyo, for a research fast breeder reactor. They saw a blue flash when they poured the fourteenth dose of uranyl nitrate solution from a 5-liter stainless beaker through a funnel into the 100-liter sedimentation tank, which had been installed there for other purpose. The total quantity of the net uranium poured was 16.6 kg, seven times the maximum allowable quantity of 2.4 kg for the tank. In order to save time, they had adopted a nonstandard procedure, one that violated even the company's three year-old operation manuals, which specified an illegal procedure. The three workers were immediately hospitalized, and two later died because of the excessive exposure to neutron and gamma rays. The equipment at the plant was designed with critically safe geometry, a safety feature that prohibited efficient operation. The sedimentation tank is used for other purposes of refining but was located there. This was an 'irradiation' accident, not a 'contamination' accident. As a result of the accident, another 150 persons received doses of radiation, but less than the maximum allowable annual dose.

No qualified engineers were in charge of the operation and workers were not educated well for the operation and accompanying risks. The company was in a difficult financial position at the time. This was not a problem of engineering ethics but of management ethics. JCO was closed due to this accident.

#### *Case 4: Snow Brand milk contamination*

On June 27, 2000, Snow Brand Milk Products Co., one of the leading milk product companies received complaints of poisoning from their low fat

milk, but the official announcement was delayed until June 29 and the recall of the products did not start until July 4. About 13,000 people suffered from the contamination resulting from the use of material that had been spoiled during a power failure in one of their plants [13].

This case revealed the following problems:

1. Important information in the company was not transferred to the persons in charge properly.
2. Instructions in the manuals were not followed although the company had been qualified by HACCP, Hazard Analysis & Critical Control Product.
3. The delay of the information transfer and decision making within the company increased the number of people affected.

An ethical engineer could have warned the management against the irresponsible operation at the plant and spared the company this disaster. These malfunctions came from a total failure of communications within the company. The company has suffered serious damage from a loss of customers.

#### *Case 5: Mitsubishi Motors' cover-up of recall*

Twice in 2000, Japanese police raided the headquarters of Mitsubishi Motor Co over the cover up of recall of defective cars and customer complaints [14]. From 1977, Mitsubishi management systematically concealed consumer complaints filed through sales agents. Top management allegedly were involved in the cover up.

## WHISTLE-BLOWING IN JAPAN

Practice of top management in Japan is changing quickly mainly due to public disapproval against unethical conduct and shareholder's lawsuits in the wake of the accidents described above. The investigations of collapse of Yamaichi Securities [15] and the cover-up of the recall by Mitsubishi Motors Co. [14] allegedly began with disclosures of confidential information by an anonymous informant. Whistle blowers are generally perceived as betraying to the organization/colleagues and untrustworthy and would not be accepted in Japanese society. The Japanese public does not see the whistle blower as a courageous protector of then public good, as often happens in the US. The author, therefore, believes that in Japan informants will continue to wish to remain anonymous.

## THE COMPLEX RELATIONSHIP OF MANAGEMENT ETHICS TO ENGINEERING ETHICS

Engineers innovate and innovation carries new risks. Since engineers are also the first to recognize the risks, at a minimum an engineer is morally

required to speak out to appropriate persons within the organization whenever he finds a possibility of danger or risk to the public.

Analysis of an accidents and mishaps often reveals that the actions of engineer were not primarily responsible. Usually the decisions of managers, both those who have never been engineers and those who have ceased to be engineers, are causes that are more important. These managers not only make critical decisions but also influence working environments and allocation of engineers, which also affect very much the consequences of engineers' actions, as all five cases described earlier illustrate. Managers have much more influence on the public welfare than engineers do.

The author believes in the need for engineering ethics education, but the education of managers in management ethics is much more important. This ought to cover standards for responding properly to information and warnings that engineers bring to them.

Education about the law sometimes works against the goal of improving ethical behavior and can become a tool to find a loophole in the legal system. In this respect, educating and making management and managers-to-be to understand (a) that corporation is a value creating entity rather than a money making entity and that money making is a necessary condition but not a satisfactory condition for corporation, as Peter Drucker has discussed [16], and (b) management ethics, are two most important measures that will protect engineers from unethical behavior.

Since engineering ethics is sometimes inextricably interwoven with management ethics, and engineers quite often take a position as a manager or management at a later stage of their careers, teaching the essence of management with engineering ethics is also valuable and important for engineering students.

#### CODE OF ETHICS FOR ENGINEERS IN JAPAN

Most of the Japanese engineering societies are primarily technical societies. Therefore, they have been slow to publish codes of ethics for their members. The following is a list of societies that

have introduced or revised their own code of ethics:

- 1996: Information Processing Society of Japan
- 1998: The Institute of Electronics, Information and Communication Engineers
- 1998: The Institute of Electrical Engineers of Japan
- 1999: The Institution of Professional Engineers, Japan
- 1999: Japan Society of Civil Engineers
- 1999: Japan Society of Mechanical Engineers
- 1999: Architectural Institute of Japan
- 2001: Society of Chemical Engineers, Japan
- 2003: Atomic Energy Society of Japan (Revised)

#### TEACHING ENGINEERING ETHICS IN JAPAN

The last several years have seen the development in Japan of the infrastructure for teaching engineering ethics, in the form of textbooks, instructors, codes of ethics, and case studies. In teaching engineering ethics, best method is to show the cases and make students think and judge by themselves.

The author thinks the students should learn not only the responsibilities of engineers but also understand how organizations function and the responsibilities of management, i.e. management ethics. Engineering students have to understand broadly what they are working for. It is somewhat difficult and sometimes misleading to teach engineering ethics narrowly without understanding the discipline and responsibility of organizations and management.

#### CONCLUSION

The author developed an introductory and engineering ethics subject in 1996 and taught more than three thousand students. Importance of teaching management ethics is emphasized. Recently, infrastructure for teaching ethics in Japan has been established due to the accreditation requirement of engineering ethics education by JABEE.

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**Hiroshi Iino** was born in December, 1933, in Kanazawa, Japan. He graduated from Tokyo University in 1956 and obtained a Master's Degree at Tokyo University in 1958. He entered in Teijin Limited in 1958 and worked as a chemical engineer and recording media engineer and top management. He enrolled in MIT Graduate School in 1963 and received Doctor of Science Degree at the Department of Chemical Engineering in 1967. He retired from Teijin Limited in 1995. He joined in the Kanazawa Institute of Technology as a professor in 1996 and started the 'Society and Engineers' classes in 1996 (Reported at ICEE2002). He published the textbook 'Becoming and Being Engineers' in 1998, and revised in 2000, 2002 and 2004. He co-translated into Japanese Professor Caroline Whitbeck's 'Ethics in Engineering Practice and Research' with Prof. J. Fudano and published as 'Engineering Ethics' in 2000. He supported the students to establish the Robot Project (Reported at ICEE2004) in the Dream Laboratories of Kanazawa Institute of Technology from 1996 to 2004.