2006-1337: IMPLEMENTATION OF A PROBLEM-FINDING AND PROBLEM-SOLVING ORIENTED ENGINEERING EXPERIMENT COURSE IN A LARGE CLASS

Nobuyuki Kitashoji, Kanazawa Institute of Technology

Dr.Eng., Assistant Professor Practical Engineering Education Program Nobuyuki Kitashoji is an assistant professor of the Division of Practical Engineering Education Program at the Kanazawa Institute of Technology in Japan. He has been engaged in the problem-finding and problem-solving oriented engineering experiment course since 1999, endeavoring to improve a learning environment and textbooks so that students will be able to flexibly apply an experiment to deal with problems in any field. He has experience in research in multiple fields, such as mechanical engineering, architectural environment engineering, aerosol and others.

Eiichi Sentoku, Kanazawa Institute of Technology

Dr.Eng., Professor Practical Engineering Education Program Eiichi Sentoku is a professor of division of practical engineering education at the Kanazawa institute of technology in Japan. Dr. Sentoku carries out the foundation experiment education that it was assembled by "the problem-finding and problem-solving type education" to aim at the active technician education for six years. He does hands on education for thirty years, and appreciates that education effect well.

Implementation of a problem-finding and problem-solving oriented engineering experiment course in a large class

Nobuyuki Kitashoji , Eiichi Sentoku
Practical Engineering Education Program
Kanazawa Institute of Technology
7-1 Ohgigaoka, Nonoichi, Ishikawa 921-8501, Japan

Abstract

Fundamental Lab for Engineering (FLE) I, II and III at Kanazawa Institute of Technology (KIT) are mandatory engineering experiment courses for 1st and 2nd year undergraduate students. In 2005, approximately 1,700 students enrolled in the courses.

The main objective of the courses is to train students in fundamental experimental skills so that students will be able to use an experiment as a flexible tool for problem-finding and problem-solving in a self-directed manner.

To realize this objective, the curriculum has been designed to instruct them to go through the whole process of experimentation starting with finding a problem followed by conducting an experiment and ending with writing a report of the experiment, and to provide them with the opportunity to have hands-on experience in dealing with all skills of the "fundamentals of the experimental method" on a theme/problem.

In order to enhance learning outcome, team-based learning and poster sessions have been adopted. Several advantages have been found in a large class.

Large lab courses have been successfully organized using various measures including tight communication between instructors, individual counseling during lessons, and safety measures by both of instructors and students.

This paper introduces the curriculum, guidelines, examples of themes / problems that students have actually tackled, the advantages of a large class and how to organize a large class.

1. Introduction

Technological innovations that have been driven through the advancement of IT have been intense in recent years. As a result, knowledge and skills soon become obsolete and useless. Therefore, it is necessary to have the ability to update our knowledge and seek new knowledge and information. It is also vital to be capable of identifying themes or problems and finding solutions to these problems using our knowledge and information.

In order to provide the students with an education designed to meet the needs of the time, KIT has promoted educational reforms and established a new curriculum including the engineering experiment course of the FLE I, II and III. This paper introduces the curriculum, guidelines, examples of themes / problems that students have actually tackled, advantages of a large class and how to organize a large class.

2. Contents of Fundamental Lab for Engineering Courses

2.1 Objectives of the Courses

The FLE I, II and III are mandatory laboratory courses for all 1st and 2nd-year undergraduate students.

The main objective of the courses is to train students in fundamental experimental skills so that students will be able to use an experiment as a flexible tool for problem-finding and problem-solving in a self-directed manner. This objective has been established as a consequence of repeated curriculum reforms since 1997.

Before 1997, these laboratory courses were targeted on letting students experience the main engineering phenomena and to teach them how to use instrumentation. Instructors designed an experiment and prepared everything for it prior to the classes, and students studied with a textbook beforehand and conducted the arranged experiment in class. This method helped students to experience various engineering phenomena efficiently but did not build their ability to update their knowledge and seek new knowledge and information or ability to identify problems and find solutions to these problems using their knowledge and information.

In 1997, the curriculum was reformed to provide students with problem-finding and problem-solving oriented teaching so that they will be able to find problems and design and implement experiments to solve these problems by themselves. However, the curriculum was not strong enough to instruct students to carry out an experiment flexibly by themselves. Therefore, the curriculum and management methods have been continuously reformed through various trials since then.

In 2004, focusing that an experiment itself is a mean to update our knowledge and seek new knowledge and information, the curriculum was set up to train students in fundamental experimental skills so that they will be able to use an experiment as a flexible tool. We consider it is vital that students be able to design and conduct experiments to draw their desired knowledge and information by themselves.

Fig.1 compares the experimental processes that students carried out in the conventional curriculum (before 1997) and the current ones. The current problem-finding and problem-solving oriented curriculum includes the whole process of experiment starting with finding a theme or problem followed by research and investigation of the theme or problem, setting of objectives, design of experiments, preparation of experiments in addition to the activities included in the previous curriculum such as conduct of experiments, analysis of results and report writing and presentations.

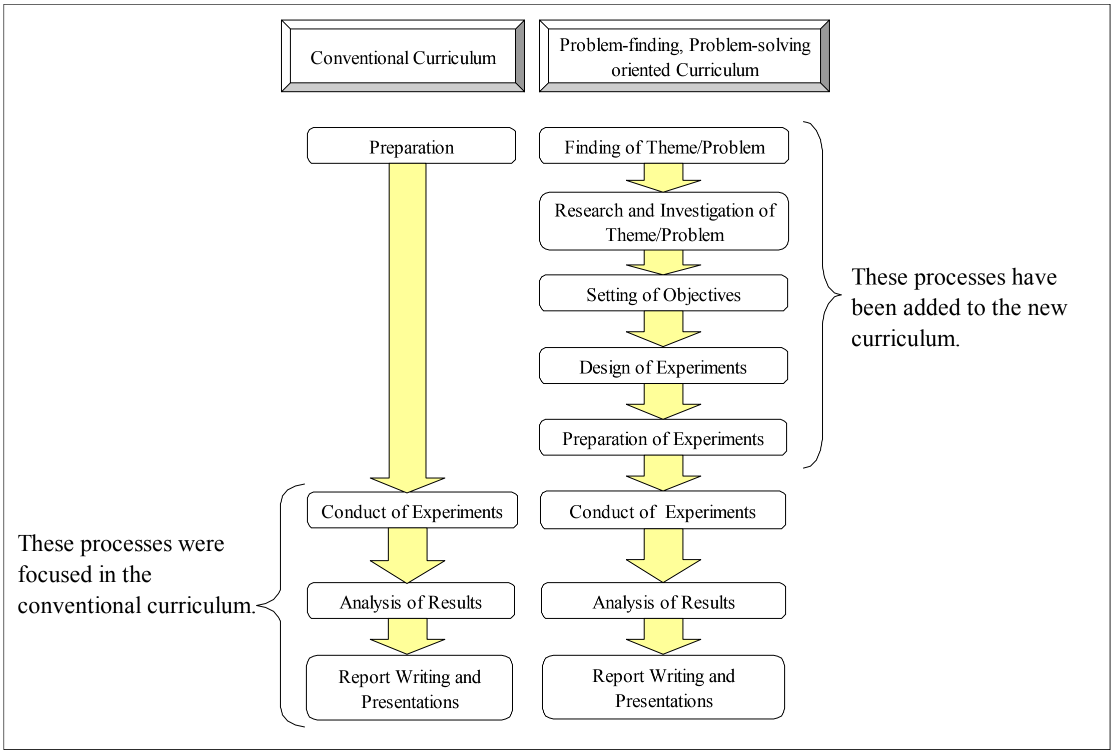

Fig. 1 Comparison of Experimental Processes that Students Work On

2.2 Fundamentals of Experimental Method

To actually conduct an experiment following the problem-finding and problem-solving oriented experimental process explained in Fig.1, various experimental skills are required. These skills have been identified and are referred to as the "fundamentals of the experimental method".

The fundamentals of the experimental method currently studied in the courses include finding of themes/problems, reproduction of the subject phenomenon, observation, research, hypothesizing about experiment results, setting of experimental objectives, safety measures, quantification of characteristics, design of experiment, understanding of constraints and modeling of the subject, consideration of measurement and evaluation method, consideration of methods, preparation of instruments, measurements, recording, data analysis, evaluation, discussion, reporting, and overall organization of an experiment (Table 1) .

Table 1 Fundamentals of the Experimental Method

Process of Experiment	**Fundamentals of Experimental method**
Finding of Theme/Problem	- Finding of theme/problem
Research and Investigation of Theme/Problem	- Reproduction of the subject phenomenon - Observation - Research
Setting of Objectives	- Hypothesizing about experiment results - Setting of experiment objectives
Design of Experiments	- Safety Measures - Quantification of characteristics - Design of experiment - Understanding of constraints and Modeling of the subject - Consideration of measurement and Evaluation methods
Preparation of Experiments	- Consideration of methods - Preparation of instruments
Conduct of Experiments	- Measurements - Recording
Analysis of Results	- Data Analysis - Evaluation - Discussion
Report Writing and Presentations	- Reporting

2.3 Guidelines for the Courses

The aim of these FLE course is that students will be able to flexibly apply an experiment for problem finding and problem solving. To achieve this aim, students must understand the fundamentals of the experimental method. Based on this idea, the guidelines for the courses have been set as follows.

(i) The students should have hands-on experience in dealing with all skills of the fundamentals of the experimental method on a theme/problem.
(ii) The students should have opportunities to deepen their understanding of each skill of the fundamentals of the experimental method.

If students understand all the skills of the fundamentals of the experimental method, they will be able to conduct an experiment commensurate with their ability at whatever level it is. The fundamentals of the experimental method are quite conceptual, and students can grasp the idea by reading books. However, in order to master the skills, they have to carry them out one by one by dealing with an actual problem. It is also crucial for them to go through all the skills of the fundamentals of the experimental method so that they will understand how to frame and use an experiment from an overall perspective.

In addition, students need to improve each skill of the fundamentals of the experimental method to improve their ability to conduct an experiment.

Following these guidelines, the outline syllabus was developed as shown in Table 2.

Table 2 Outline Syllabus

Course	Key Objective	Details	Note
FLE I	Safety Session	Training in safety-minded behavior during experimental operations	Discussion
	Measurements of Length	Resourceful ways of measuring length	Pre-experimental practice
	Observation	Observation of the qualitative characteristics of a subject	
	Quantitative measurement of characteristics and Reporting	Quantitative measurements of the characteristics of a subject and preparation of a simple experiment report	An experiment using all skills of the fundamentals of the experimental method at each course
FLE II	Measurement-focused	Experiments using various measuring	
FLE III	Experiment with modeling	Experiments applying modeling and simulation understanding of constraints	

The FLE I offers a safety session to introduce all safety-related advice and activities. The students then work on simple assignments focused on measurements, observation and quantification of characteristics.

In each of the FLE II and III courses, the students design and run an applied experiment. The FLE II involves applications of measurements. The FLE III focuses on modeling and simulation.

In the safety session of the FLE I, students discuss safety measures. In the lessons of measurements of length and observation, they work on pre-experimental practice. Then, in the lessons of quantitative measurement of characteristics and reporting, FLE II and III, they actually conduct an experiment covering the fundamentals of the experimental method focusing the respective key objectives.

2.4 Examples of Themes / Problems

To allow the students to focus on the fundamentals of the experimental methods, the range of experimental subjects that students work on are not limited to engineering-related matters but extended to any phenomenon familiar to them. Students should work on a simple subject that they can easily handle, otherwise they will not be able to design an experiment nor go through the all expected skills.

The themes / problems that students have actually tackled are exemplified.

(1) FLE I Theme 1 "Measurement of Length"

The target is to find a resourceful way of measuring length. A typical example is to measure long distance by counting steps or the rotation number of a bike tire, or to measure height by computing the descent velocity of a balloon and the time required for it to drop to the ground. Examples of things that have been measured:

- The ceiling height of a classroom
- The width of a blackboard
- Body height
- The height of a school building
- The circumference of a column

(2) FLE I Theme 2 "Observation"

The target is to observe phenomena and explain their characteristics using illustrations and words. For example:

- When a well-shaken soda bottle is opened, how soda splashes
- When a cup filled with water is tipped over on a table, how the water spreads on it
- How a chocolate bar melts
- How a candle burns
- How the sand of a sand clock flows

(3) FLE I Theme 3 "Quantitative measurement of characteristics"

The target is to observe characteristics of a subject and quantitatively measure the characteristics. Such as

- How condensation builds on a juice-filled glass
- How a pendulum swings
- How a drop of water slides down a slanted plate
- How pasta is cooked
- How milk boils

(4) FLE II Theme "Applications of measurements methods"

The target is to find methods for measuring various phenomena in accordance with the experimental objectives. For example:

- How to measure a big soap bubble
- How to measure fatigue when writing with a pen
- How to measure the brightness / darkness of a road in street light
- How to measure how easily a sticker comes off
- How to measure how tough / tender grilled meat is

(5) FLE III Theme "Experiment with modeling"

The target is to conduct experiments to find out the characteristics of phenomena by applying modeling and simulation approaches. Such as

- How to make good tasting coffee

- A broom that collects dust well
- How to cool body temperature using an electric fan
- How to improve the ventilation of a room
- How to prevent the temperature in a car from rising

2.5 Approach to Improve the Effectiveness of Learning

(1) Team-based Projects

The FLE courses involve a team-based project. The team-based learning experience develops the students' cooperative and leadership capabilities and deepens their understanding through collaborative work. Each team is composed of 5 or 6 students. Fig.2 shows a scene of team-based experiment.

Fig. 2 Team-based Experiment

(2) Poster Session

It is desirable for students to work on as many themes as possible in order to acquire a broad understanding of the fundamentals of the experimental method. However, they can work on only a limited number of themes in the class due to time constraints. To broaden their understanding, it is crucial for students to learn from the various experiments of their peers. In this respect, conducting poster sessions provides them with a great opportunity to learn about various experiment examples that other teams have conducted.

3. Effective Management of a Large Class

3.1 Students in the Courses

The FLE I, II and III are mandatory courses for all first and second-year undergraduate students. In 2005, approximately 1,700 students enrolled in the courses. Their majors were in Engineering, Environmental Engineering and Architecture, or Informatics and Human Communication, thereby their topics of interest dealing with an experiment are diverse ranging from physics, chemistry, biology and psychology.

The 1,700 students enrolled in the courses are divided into eight classes (Fig.3). Each class consists of up to 290 students and is guided by five to eight instructors, meeting weekly in 2-hour sessions over a period of ten weeks.

Fig. 3 Guidance

3.2 Advantages of a Large Class

(1) Many Posters in Poster Session

A poster session is especially effective in a large class. A poster session in a large class with many experiment teams and a variety of experiments exposes students to various experiment examples of their peers. This helps students understand a broad range of experiments (Fig.4). Each of FLE I, II and III has about 50 teams and thereby 50 posters.

Fig. 4 Poster Session

(2) Extensive Experimental Instruments Available

To enable students to conduct a wide variety of experiments, various types of experimental instruments are set up in a room and are available for examination (Fig.5). Since the FLE courses are taught in large classes with many experiment teams, each year has various experiment themes which have not been conducted before. To enable students to conduct these unprecedented experiments, new instruments have been additionally purchased every year.

As a result, the number and kind of instruments have grown substantially. In 2005, the number of these instruments totaled about 240 kinds.

Fig. 5　Instrument Check-Out Desk

4. How to Organize a Large Class

To maximize the effect of problem-finding and problem-solving oriented experiment lessons in a large class, various activities are conducted.

4.1 Tight Communication between Instructors

To effectively organize the classes, frequent and tight communication between the instructors is required. In the FLE courses, all instructors hold a weekly class organization meeting to discuss and confirm the following.

- Overall lesson schedule
- Syllabus
- Content details of each lesson
- Preparation for each lesson
- Content of the students' assignments and evaluation criteria and deadline of the assignments
- Forecast of possible students' activities
- Accident forecasting
- Other administrative things

4.2 Individual Counseling

To deepen the students' understanding of the lesson contents and to develop their experiments, the instructors communicate with their students through individual counseling or by giving comments and advice on the assignments submitted by the students.

In addition, during the class, the instructors confirm the safety conditions and give students advice, instruction and answer questions of the students (Fig.6).

Fig. 6 Instruction of how to use instruments by the instructor

4.3 Safety Measures

In order to maintain safety in lessons where students conduct a wide variety of experiments, not only safety measures by the instructors but also each individual student's awareness toward safety are required. The following measures have been taken to ensure safety-minded behavior.

4.3.1 Safety Measures by Students

(1) Safety Training Session

The first lesson of FLE I teach in detail the safety measures that each student is required to follow during the lessons of the FLE courses.

Main contents are as follows:

- Basic ideas of safety preservation
- Rules in the laboratory
- Safety-related information in the laboratory (Location of emergency exits and fire extinguishers.)
- Safety measures based on Heinrich's law (Refer to 4.3.1 (2) for details.)
- Accident forecasting (Refer to 4.3.1 (3) for details.)

(2) Safety Measures Based on Heinrich's Law

Heinrich's Law suggests that eliminating minor accidents, which are potential risk factors for further accidents, might help in preventing major accidents. Based on this law, the students submit a report of minor accidents they have experienced and share this information in class.

(3) Accident Forecasting

At the experiment planning stage, the students are instructed to forecast any accidents that may occur during their experiments and how to prepare to handle the situation. They write down their forecast in their experiment plan sheets and which the instructors check and give safety advice (Fig.7).

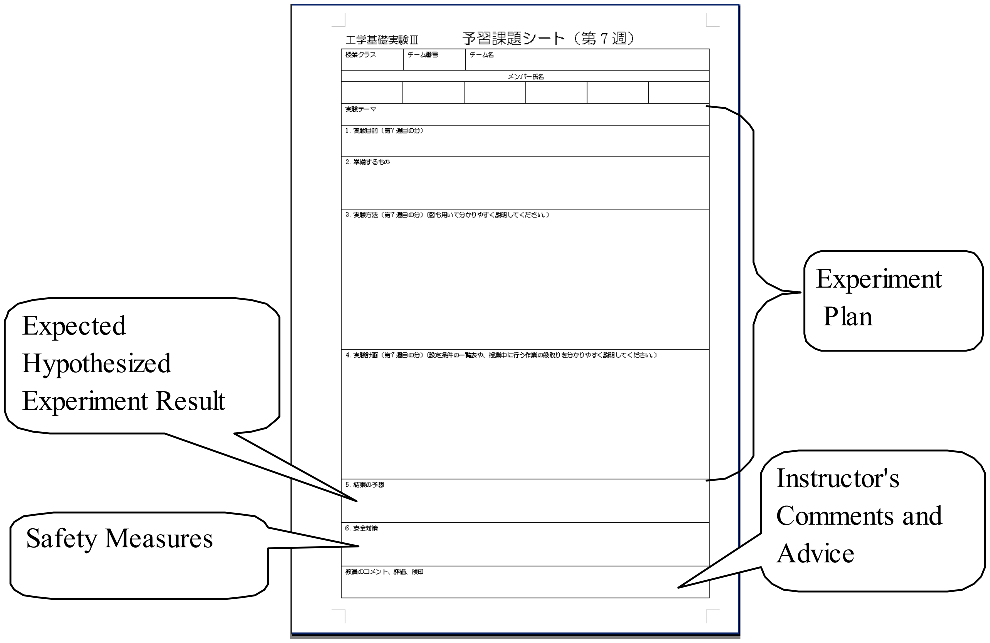

Fig. 7　Experiment Plan Sheet

4.3.2 Safety Measures by Instructors

(1) Accident Forecasting

In a weekly class organization meeting, the instructors forecast any dangers that can arise during the next lesson and discuss preventive measures.

(2) Safety Check of the Lab Every Lesson

Any accidents or abnormalities that have occurred in the lessons should be promptly informed to all of the instructors. To facilitate this process, the instructors keep a record of safety checks by filling out the Lab Management Check Sheet every lesson (Fig. 8). The check sheet includes the following points.

- Date, Time, Weather, Class code
- The condition of the lab before the lesson
- Types of experiments conducted
- Accidents or abnormalities occurring during the lesson
- Check on cleaning of the lab after the lesson
- Things left behind
- Check for fire, water and electricity
- Check on locking the lab

After each lesson, the instructor in charge of safety management checks the filled Lab Management Check Sheet and immediately takes measures if any problems or abnormalities are found. In addition, any crucial matter is discussed at the class organization meeting.

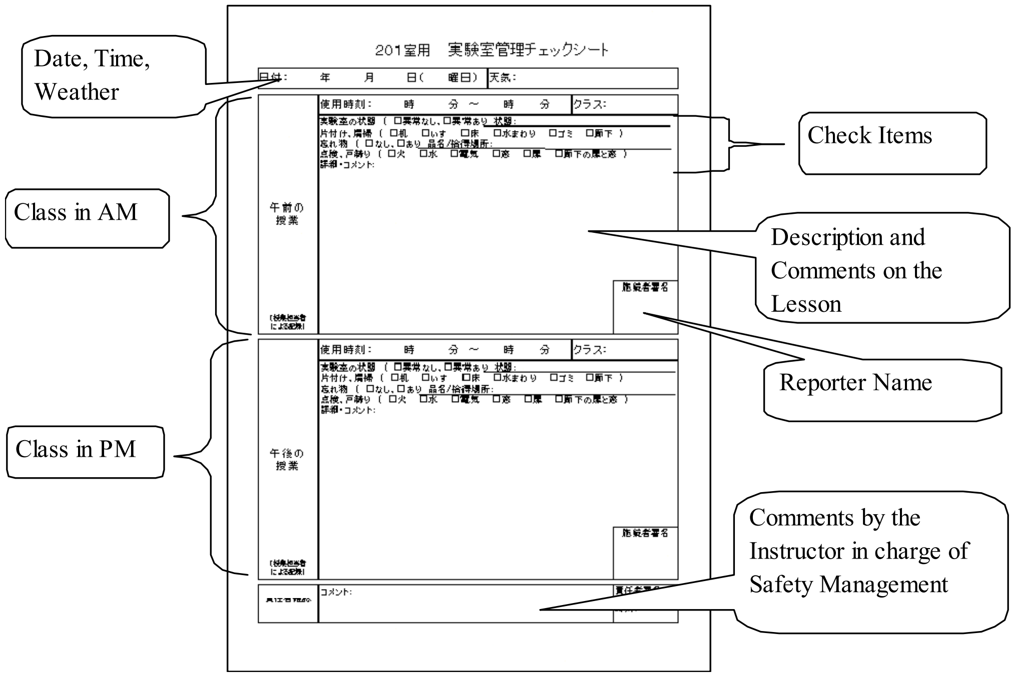

Fig. 8　The Lab Management Check Sheet

(3) Regular Check of the Lab

The instructors conduct a regular check of the labs every month. The major checkpoints include fire extinguishers, emergency escape apparatus, emergency medical kit and hygiene in the lab. In addition, the university carries out safety audits of the labs every year.

4.3.3 Actual Safety State

According to the reports of minor accidents based on the Heinrich's Law submitted by the students in 2004, 95 cases of accidents or damages occurred. The details are no injuries, 10 cases of potential risk factors and 85 cases of instrument damage. The breakdown of the damaged instruments was 73 cases of glass equipment such as beakers, 12 cases of experimental instruments.

5. Questionnaire Result

The satisfaction level was evaluated by having students fill questionnaires at the end of each course in 2004. The ratio of respondents is 91 % (FLE I), 81 % (FLE II) and 93 % (FLE III). The questionnaire result shows that about 90% of the students of each course answered "Very Satisfied" or "Fairly Satisfied".

Frequently given opinions are as follows:

(1) Satisfied

- Conducting an experiment on the theme found in a self-directed manner was interesting.

- We learned a series of experiment processes.
- A poster session gave us a good opportunity to learn about the experiments of our peers.
- It was a hard lesson for me, but it gave me a sense of mastery.
- I acquired report writing skills.
- I learned the merits of a team-based activity.

(2) Not satisfied

- The self-directed work was too difficult for me.
- It took too much time for me to work on this course and not enough time left for studying other courses.
-There was variation in grading standards among instructors.
- A wider variety of instruments should have been offered.

6. Conclusion

This paper explained the outline, curriculum, and examples of themes / problems that students have actually tackled in the Fundamental Lab for Engineering I, II and III, and the advantages of a large class and how to organize a large class.

The main objective of the courses is to train students in fundamental experimental skills so that students will be able to use an experiment as a flexible tool for problem-finding and problem-solving in a self-directed manner.

Taking advantage of a large class, the courses have been designed to expose the students to a wide range of experiments through a poster session.

To enable them to conduct a wide variety of experiments, various types of experimental instruments are set up in a room and are available for examination.

In order to safely conduct these large-class lab courses, various safety measures have been made, which include tight communication between instructors as well as between students and instructors, safety measures based on Heinrich's Law and accident forecasting. As a result, no major accident or injury was reported in 2004.

The questionnaire result shows that about 90% of the students of each course answered "Very Satisfied" or "Fairly Satisfied" in 2004.

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