Practical Manufacturing Education in the Mechanical Engineering Course at the School of Science and Engineering, Kokushikan University

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Abstract
This article introduces examples of practical manufacturing education which use active learning methods in the Mechanical Engineering Course at the School of Science and Engineering, Kokushikan University, as well as summarizing their educational effects. In recent years in Japan an increasing number of people, particularly young people, have lost their interest in science and engineering. However, manufacturing industries are key industries for Japan and it is necessary to continuously develop these industries and train engineers to work in the industries. Therefore, our university focuses on manufacturing education throughout the four year university course and we teach specialist skills on practical themes. It was discovered that when active learning methods were used they were effective and students became more interested in engineering.
Keywords: Project-based learning, Manufacturing education, Mechanical engineering education

1 Introduction
We come into contact with various machines in our daily lives. For example, we cook rice using rice cookers. We use trains and buses to commute. We use cash dispensers at banks. Processing machines and manufacturing robots are used in factories, and heavy machinery is used on construction sites. These machines use electrical energy or chemical energy derived from fossil fuels as power sources. The job of the engineer is to create and utilize machinery that helps people and society. In this article a “machine” is defined as a piece of equipment that does useful work for people or society using some sort of energy. “Manufacturing” is defined as creating tools and equipment including machines.

Japan is natural resource poor and has to import most of the natural resources it uses from overseas. The only way that Japan can create wealth for Japanese society is to process imported raw materials into high value-added products. Therefore, we cannot allow our manufacturing industries to decline, and we need to continue to hand down our technologies as well as developing them. For this reason, institutions for higher education are increasingly expected by society to train engineers who will work in manufacturing industries. There are endless occurrences of accidents that destroy people’s lives, involving machines which are supposed to serve people and society. For example, there are numerous tragic train and air accidents as well as accidents involving play equipment which is supposed to give joy to people. Parts of machinery always contribute to the causes of these accidents. Engineers create equipment and tools that are useful for people and society, but they can also contribute to major accidents if one mistake is made in their design. Therefore, there is no doubt that the training of high quality engineers who have practical skills is an important and urgent issue.

However, it has been pointed out that young people have lost interest in manufacturing in recent years and the tendency not to choose science and engineering as their major has become predominant. This tendency is caused by poor public awareness about the occupation and poor working conditions. Another cause is the lack of attractive educational curriculums and teaching staff at institutions for primary, secondary and higher education.

Kokushikan University focuses on practical education. Because the university is located in the middle of Tokyo, in order to differentiate ourselves from other institutions for higher science and engineering education which exist in the Tokyo Metropolitan area, we need to put our full energies into practical manufacturing education while at the same time tapping into the advantages of being located in the middle of Tokyo.

Therefore, the Mechanical Engineering Course at the School of Science and Engineering provides practical education offering specialist skills, by focusing on manufacturing throughout the four years at the university. This article summarizes the practical manufacturing education methods for the first year students at the university and examines their effects by looking at the results of a questionnaire survey conducted for students. It aims to clarify the desirable direction for the development of introductory education for students who wish to become mechanical engineers, who do not have specialized knowledge.

2 An Outline of the manufacturing education curriculum for the mechanical engineering course

2.1 The current situation and challenges for manufacturing education
The fact that science and technical skills education

is neglected in primary and secondary education greatly contributes to the small number of students who choose science and engineering as their major in higher education. There are fewer teachers of science and technical skills than teachers of Japanese, mathematics and English. For science and technical skills, one teacher has to teach two or three times more students than teachers of Japanese, mathematics and English. As an example, **Table 1** shows the number of students per teacher for each subject at municipal junior high schools in Suginami City, Tokyo. In this example, one science teacher teaches three times more students than the mathematics teachers. There is no full-time technical skills teacher and the schools employ only part-time teachers. One of the factors which created this situation is competition between junior high schools to have the largest percentage of graduates entering high schools. The competition created a tendency where junior high schools focus exclusively on subjects that are designated by high schools as entrance examination subjects. There are also cases where mathematics teachers have to teach science. The same tendency is seen in high schools: they focus on subjects that are designated by universities as entrance examination subjects. This is why many students who enter university have only studied "mathematics I" or have never studied physics. It is difficult to solve this problem because, if universities add "mathematics III" and physics to the entrance examination subjects for example, the number of students who wish to enter the universities may decrease. Therefore, for first and second year students at university, it is necessary to give both education which supplements primary/secondary education and education on specialized subjects in a balanced manner. **Figure 1** is a diagram showing the areas of study that have to be covered by higher education institutions, by expressing the flow of primary, secondary and tertiary education on the cross axis and the expansion of education into specialized subjects on the vertical axis. The areas of study that have to be covered by science and engineering universities range from education which supplements primary and secondary education to practical, higher education that teaches specialist skills. In the past, practical, higher specialist skills education was given mainly by companies in the form of training courses for newly employed engineers or on-the-job training (OJT). Some of these educational activities for engineers are now conducted before students graduate from university, through internships and lectures by educational staff who used to work at companies. This is because many companies began to expect universities to train students to become engineers with practical skills so that they can start to work immediately after being employed. The reason for this is that companies no longer provide the long-term training programs for new employees that used to be provided in the bubble period (from the 1980s and to the mid-1990s). Instead, the new employees are given work to do as soon as they have completed a basic training course which lasts a few days. As shown in **Fig. 2**, higher education institutions began to provide practical education in addition to the specialized subject education that was traditionally taught. For example, many universities prepare curriculums which teach practical, advanced specialist knowledge as distinctive services, which had been taught at companies in the past. In Japan, where the child population is declining, universities which offer such distinctive education are likely to become more competitive because they increase the chance of their graduates obtaining jobs, generally speaking.

Table 1 The number of students per teacher for science and technical skills in primary and secondary education

subject	The number of pupils in a teacher's undertaking	
Japanese	75	(-)
Mathematics	75	(50)
English	150	(75)
Science	150	(-)
Industrial arts	-	(150)
Home economics	-	(150)
Social studies	150	(150)

The research year : 2009, (include part-time teacheres)

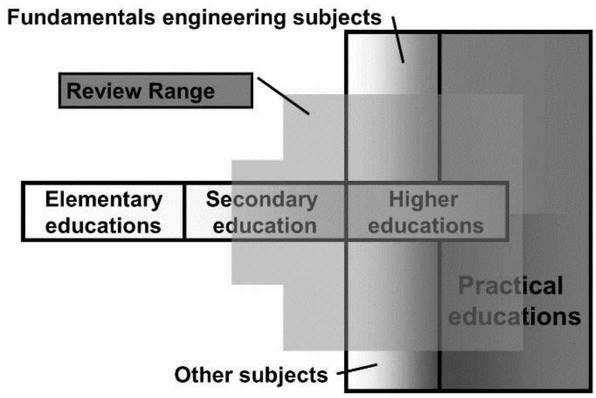

Fig.1 The cross axis and the vertical axis of engineering education

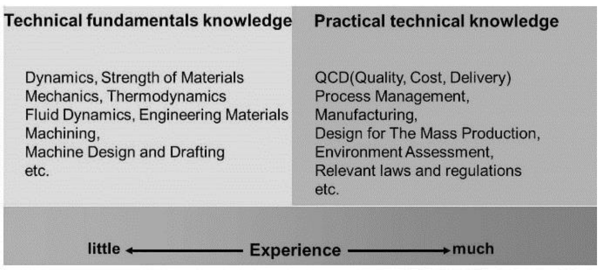

Fig.2 Specialized education at higher education institutions

In recent years, the BRICs (particularly China) have been committed to introducing manufacturing technologies into their countries. This is because the international division of labor is progressing and manufacturing businesses are moving to countries which have cheap and plentiful labor. For example, China produces more than 40% of TV sets and more than 80% of PCs worldwide, while Japan produces only a few percent. There is no doubt that the only way for Japanese manufacturing industries to survive is to pursue high quality and high productivity which cannot be achieved in the BRICs. However, there is a shortage of new engineers due to the declining birthrate and difficulties in handing down technical skills from skilled engineers to new engineers. Training young engineers who can work in manufacturing industries is a major challenge for Japan.

2.2 The Technical Skills Education System for Manufacturing Used in the Mechanical Engineering Course

Figure 3 summarizes the education system for the Mechanical Engineering Course. In the course, the academic content to be learned is divided into four areas: mechanical dynamics, material dynamics, thermodynamics and hydrodynamics. The three concentric circles indicate the following: the central or core region indicates the basic knowledge needed to learn mechanical engineering including science, mathematics, etc. taught in high schools. The middle region indicates the specialized subjects taught at the university. The outer region indicates practical specialized education. The content of the course moves from the center of the circles outwards as students progress through the university.

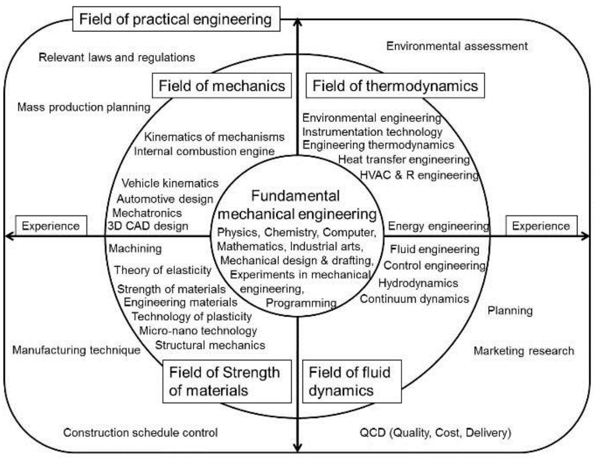

Fig.3 Manufacturing education in the mechanical engineering course at the school of science and engineering, Kokushikan university

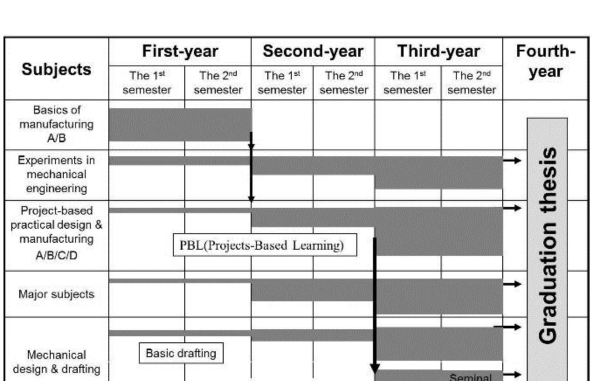

Fig.4 Subjects related to manufacturing taught in each year

Figure 4 shows the year in which each manufacturing-related subject is taught. For first year students who have not been taught the specialized subjects, education on manufacturing is given based on the knowledge that the students obtained through science and technical skills education in high school. In the first year, the "Basics of Manufacturing A/B" are taught with the aim of increasing the creativity of students and to improve their ability to use basic engineering knowledge to make things. In the second and third year the students learn specialized subjects. The students are given themes for experiments and exercises through which they can check whether they have obtained expertise in the subjects. In particular, in the "Designing and Manufacturing Projects A/B/C/D," students are encouraged to follow the project procedures of "Plan," "Do" and "See." Meetings are also held and students present their project results, so that they can acquire presentation skills and be able to summarize and self-assess their projects. These experiences are eventually utilized in the graduation research that the students conduct in the fourth year.

3 Examples of manufacturing education given in the first year at the university

3.1 The Schedule and outline

In order to study specialized science and engineering subjects, it is important that students have the ability to understand the connection between the technologies used in equipment and natural science theories. In particular, students who have just entered the university tend to have learned mathematics and physics as subjects needed for university entrance exams and most of them do not understand the connection between the subjects and how machines work. Therefore, in the first year, we find that it is effective to give manufacturing education using themes familiar to students, based on the knowledge that they had obtained before entering the university, such as the mathematics and physics they learned in high school. This section gives examples of lessons taught in "Basics of Manufacturing A/B" for first year students.

Table 2 Content of "Basics of Manufacturing A/B"

Subjects	Theme	Related major subjects
Basic manufacturing A	Paper plane	Hydrodynamics
	Bamboo dragonfly	Fluid engineering Mechanics
Basic manufacturing B	Catapult	Mechanics Thermodynamics
	Spaghetti bridge	Strength of materials
	Coil spring car	Mechanicals Thermodynamics

"Basics of Manufacturing A" is taught in 15 lessons in the spring term. "Basics of Manufacturing B" is taught in 15 lessons in the autumn term. **Table 2** shows the connection between the themes taught and four specialized areas of study which are included in **Fig. 3** above. The themes were chosen so that all the mechanisms can be understood using knowledge obtained in primary and secondary education. The goals were set so that students can create assigned products based on natural science theories, rather than through trial and error. The lecturer in charge of each theme guides the students so that they become interested in engineering knowledge that will be taught in the specialized subjects in the second and third grades. **Table 3** shows an example of 15 lessons for "Basics of Manufacturing A." Five to seven lessons are given on each theme. Many hours are allocated for elaborating plans and designing so that students have plenty of time to think. After the first assessments of the designed and created products, the students are asked to redesign and modify the products based on the assessment results. This process is designed to increase the problem solving abilities of the students, which will then become useful in their graduation research.

Table 3 An example of the schedule for "Basics of Manufacturing A"

	Contents			Contents	
1st	Guidance		9th	Concept consideration	
2nd	Concept consideration		10th	Design and trial manufacturing	
3rd	Design and trial manufacturing		11th	Design and trial manufacturing	
4th	Design and trial manufacturing	Paper plane	12th	1st evaluation	Bamboo dragonfly
5th	1st evaluation		13th	Improvement	
6th	Improvement		14th	2nd evaluation	
7th	2nd evaluation		15th	Presentation	
8th	Presentation				

3.2 Examples of Lessons for Specific Themes

Figure 5 shows the outline of the manufacturing of a model trebuchet, as part of "Basics of Manufacturing B." Students design trebuchets using the designated materials in the way they think is best. The cup is made of plastic. All the materials needed including the cups and pieces of wood are supplied by the school. The students design the angle at which the cup should be attached, the length of Component 3, the location of the wire which serves as the fulcrum, the angle at which Component 2 should be installed, and so on. They then make their model trebuchets. A bouncy ball is placed in the cup when testing the trebuchets. Students create the optimum structures that can throw a bouncy ball a certain distance, while reviewing what they learned in high school such as centrifugal force, the rotation of objects, kinetic energy and torque. **Figure 6** shows some examples of model trebuchets made by students. **Figure 7** shows a student evaluating the performance of his model trebuchet. Each product is different as it was made based on a design created by each student. In the evaluation, various tests are conducted in addition to checking the distance, so that students can learn more from the experiments. For example, they study the trajectory of the ball and the relationship between the height and the distance the ball achieved, by placing an obstacle in front of the trebuchet, as well as evaluating accuracy using a target.

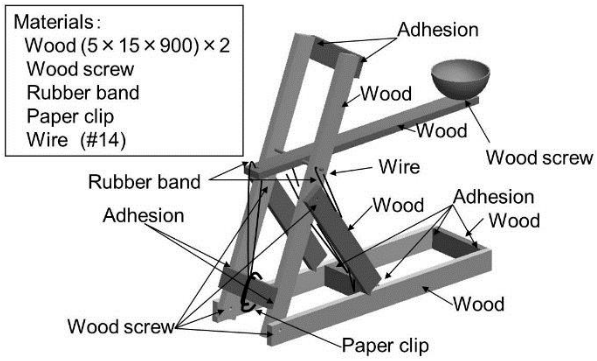

Fig.5 The outline of the model trebuchet

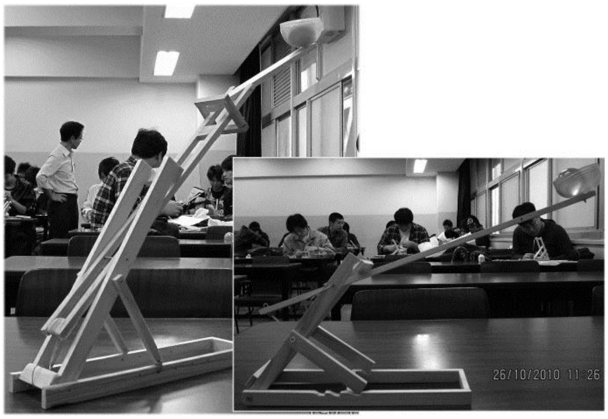

Fig.6 Examples of trebuchets made by students

Fig.7 Evaluation of the trebuchet that the student made

Table 4 Specifications for designing a spaghetti bridge

Design specifications
・Empty weight : 100 g or less ・Span of bridge : 600 mm or more ・Basic for evaluation : [Collapse load] ／ [Empty weight]

The next example is the "spaghetti bridge." **Table 4** shows the specifications for designing a spaghetti bridge. Using dry spaghetti, each student designs and makes a model bridge by cutting spaghetti with a knife and sticking pieces together with instant glue. Through this experiment, the students deepen their understanding of strength so that they are ready to learn the specialized subjects categorized in material dynamics. In order to help the students to be ready for specialized subjects, supplementary teaching materials are used to explain the basic principles of material dynamics as shown in **Fig. 8** and **Fig. 9**, as well as letting students explore the flexural strength of one piece of dry spaghetti, before they start designing their spaghetti bridges. **Figure 10** shows some examples of spaghetti bridges that students made. Because students were enthusiastically involved in the exercise, many products had structures that took into account the aesthetics as well as the strength.

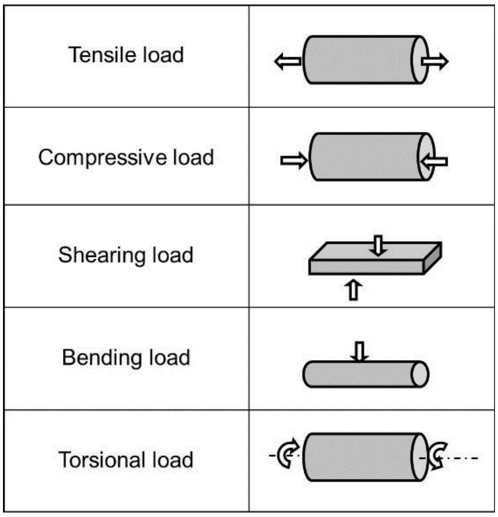

Fig.8 An example of the supplementary teaching materials (Types of loads)

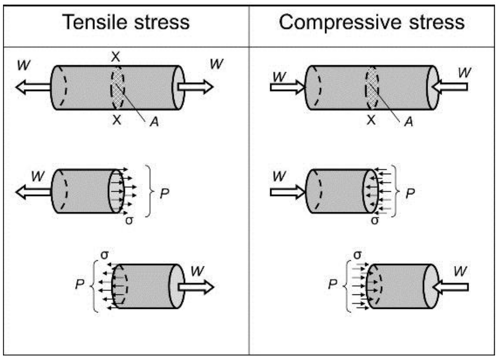

Fig.9 An example of the supplementary teaching materials (Normal stress)

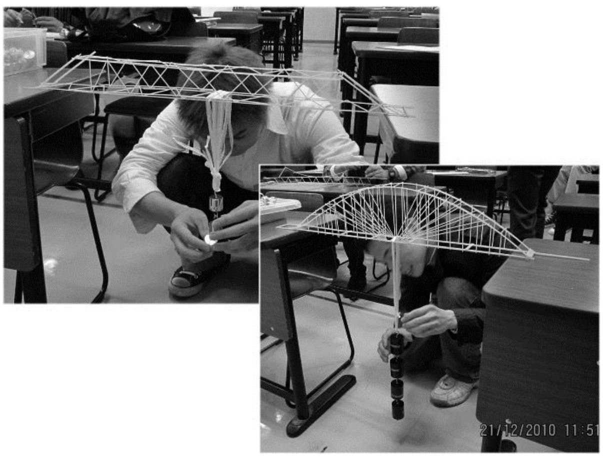

Fig.10 Examples of spaghetti bridges made by students

3.3 Questionnaire surveys for the evaluation of lessons

"Basics of Manufacturing A/B" have been taught from 2007 to 2010, and 50-80 students attended the lessons. **Figures 11**, **12** and **13** show the results of the questionnaire survey for the evaluation of "Basics of Manufacturing A" conducted in 2010. **Figure 11** shows how satisfied the students were regarding the achievement levels for the lesson goals. Those who answered "very satisfied" and "moderately satisfied" accounted for 64% of the respondents, and only a small percentage of students said that they were not satisfied. This shows that the goals set for the series of lessons were generally appropriate. Satisfaction levels should increase further if the lecturers explain the goals and the aims of the lessons more clearly. **Figure 12** shows the level of student understanding regarding the content of the lessons. Those who answered "I understood well" and "I mostly understood" accounted for 74% of the respondents. This shows that the methods used in the series of lessons were highly effective in teaching the

Fig.11 The results of the questionnaire survey for the lesson evaluation (No. 1)

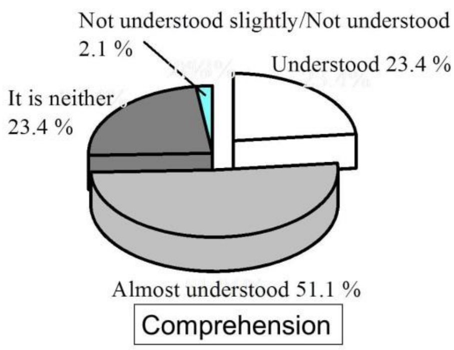

Fig.12 The results of the questionnaire survey for the lesson evaluation (No. 2)

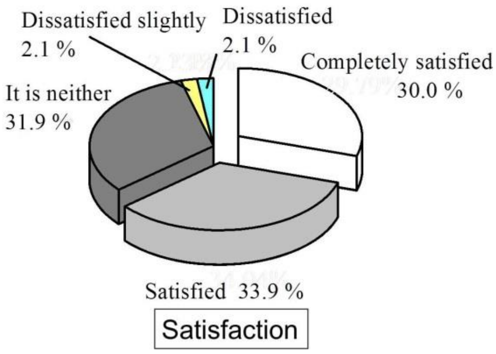

Fig.13 The results of the questionnaire survey for the lesson evaluation (No. 3)

students. **Figure 13** shows the level of student satisfaction regarding the lesson content. Those who answered "very satisfied" and "moderately satisfied" accounted for 72% of the respondents. This shows that the lessons satisfied the majority of students.

4 Conclusion

In order to improve the methods for educating potential manufacturing engineers, the School of Engineering was reorganized into the School of Science and Engineering in 2007, and also new curriculums for teaching practical technical skills for first and second year students were developed and put into practice. Through the experience, it was discovered that the new curriculums made students more interested in engineering and that they were effective educational methods.

When looking at history, many soldiers became heroes and many politicians became history makers. However, engineers have always created infrastructure for society. It is an important and satisfying occupation because without engineers the foundations of society cannot be created. Future engineers and those who educate future engineers should keep this in mind, particularly in Japan which relies on technology-based development. We have proven that by committing ourselves to training engineers while understanding the importance of the occupation makes students more interested in the subject and creates better educational results. We now know how to improve our education, and therefore I sincerely hope that relevant university departments will work together to employ practical and active learning methods in order to improve science and engineering education.

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