MECHANICS PROGRAMMES UNDER THE JAPANESE INSTRUCTION THEORY HEC

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Around 1950, Dr. Kiyonobu Itakura of the Japanese National Institute for Education, a historian of science and educator, conducted a study of Japanese students' understanding of scientific knowledge, concluding that they clung to intuitive concepts acquired through their daily experience. To overcome these intuitive concepts, Itakura advocated Kasetsu Jikken Jugyo*, or Hypothesis Experiment Class (HEC) in English, in 1963. The lesson plan 'Spring and Force', developed and published in the early days of Itakura's work, remains highly effective at teaching statics in schools, even today.*

Keywords: mechanics, conceptual understanding, learning theory

INTRODUCTION

In 1963, Dr. Kiyonobu Itakura (a senior scientist emeritus at the Japanese National Institution for Education) advocated a instruction theory called the Hypothesis Experiment Class (HEC) based on his study of the history of science and scientific epistemology (Itakura, 1963). Over 50 lesson plans, termed *Jugyosho* (H-E Classbook in English, or Classbook for short) that created enjoyable science classes were published. These plans cover a wide range of fields, from biology to mathematics, even to social science.

Although the concept of HEC is acknowledged in Japan as a fruitful achievement, it is little known outside the country since its basic literature has not been published abroad in any foreign languages. In this paper, we will introduce an outline of the Classbook for 'Spring and Force', which was Itakura's initial representative work and an achievement of Itakura's thesis.

COGNITIVE RESEARCH AND HEC

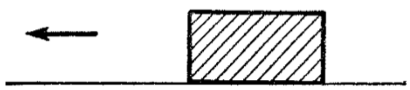
Around 1960, Itakura published the results of his study of students' understanding of scientific knowledge, based on his prediction that the confusion about scientific knowledge conception in the history of science would also be seen in the confusion of students in science class (Itakura, 1964; Itakura & Kubo, 1965; Iwaki, Kamikawa, & Itakura, 1959). A sample of the research done by Itakura is shown below (Figures 1 and 2).

[Problem 1] (Target: 93 students in a public school, 13 years old) If this were a smooth table, and air resistance and friction were vanishingly small, sliding the block will lead to which of these results?

(i) The block will run to the end of the earth.

(ii) The block will stop after a little because of its weight.

(iii) The block will stop for another reason.



N	1	0	1
i	14	14	28
ii	27	24	51
iii**	4	9	13

Figure 1. Problem 1 with results

[Problem 2] (Target: 77 students in a private high school, 16 years old)

A disk is moving horizontally on ice.

i. Indicate all forces acting on the disk.

ii. Indicate these force on the figure.

(In all, 39/77 students placed an arrow pointing ahead)

iii. How much distance will the disk go if its initial speed is 2.8 m/sec and the coefficient of kinetic friction is 0.02.

(Correct answers were given by 10 students; 8 answered correctly on all questions)

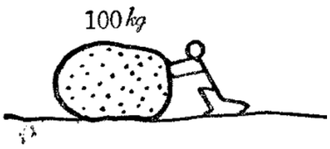
Figure 2. Problem 2 with results

After realising that even privileged private-school students could not answer these problems correctly, Itakura characterised students as believing in medieval impetus or vis impressa mechanics.

He published his results on research into frictional force (Figure 3).

[Problem 3] (Target: 93 students at a public school, 13 years old)

There is a stone of about 100 kg. If there is friction, how much force is needed to move this stone horizontally.



i. 100 kgw.

ii An equal amount to the frictional force.

iii The frictional force + 100 kgw.

iv. The frictional force or 100 kgw (whichever is larger).

v. More than 100 kgw.

vi More than the frictional force.

viii. More than the frictional force + 100 kgw.

ix. Impossible to answer from this information alone.

	Number of Answers		
	A (46)	B (47)	(93)
N*	0	0	0
i	0	1	1
ii	1	1	2
iii	27	15	42
iv	0	3	3
v	2	5	7
vi	1	2	3
vii	13	18	31
viii	1	1	2
ix	1	1	2

* N means blank.

Figure 3. Problem 3 and results – (Frictional Force)

Most students (45%) thought that friction + 100 kgw or more is needed to move the block. Itakura noted that this result is similar to Bradwardine and Buridan’s mechanics from the mid-fourteenth century. Though Buridan accepted inertia, he thought that the force applied needed to be greater than the weight of the object which was being moved.

He also published his results on statics (Figure 4).

[Problem 4] (Target: 93 students in a public school, 13 years old)

There is a metal bottle with a vacuum inside. When hydrogen is put in this bottle, the weight of the bottle is

i. lighter than the bottle with the vacuum.

ii. heavier than the bottle with the vacuum.

iii. the same weight.

iv. dependant on the weight of hydrogen put into bottle.

N	0	1	1
i	19	18	37
ii	10	14	24
iii	8	9	17
iv	9	5	14

Figure 4. Problem 4 and results – (Statics)

For this problem, 40% students answered i (It is lighter than vacuum bottle), an answer consistent with Aristotelian mechanics.

From his research, Itakura concluded that the students' common or intuitive concepts sometimes prevented them from understanding scientific concepts.

STRUCTURE OF HEC

Basic idea of HEC

To overcome students' intuitive concepts and bring them to a true understanding of science, Itakura began advocating HEC in 1963 (Itakura, 1963). Itakura stated that to overcome students' concrete intuitive concepts, the conflict between scientific logic and common intuitive logic must be made clear, so that students realize the superiority of scientific logic and concepts (Itakura, 1967).

Classbook

The fundamental concept of HEC is that 'all preparation should be supported, so that any teachers who is not master or veteran but is eager to perform good instruction can achieve their goal'. To realise this, Classbooks, which have the multiple functions of instruction manual, textbook, and notebook, are prepared. Using a Classbook, anyone have good lessons.

Evaluation of the class

The goals of HEC are as follows (Itakura, 1966).

1. The concepts and laws taught in the Classbook will be mastered by the students.

2. All students will enjoy science and their lessons.

To evaluate the first goal, the average score on the final test should be 90%. To achieve the latter goal, more than half of students will respond to a questionnaire that they like science or the HEC lesson, if the questionnaire is conducted after an HEC lesson, and none (except for two or three anomalous students) would answer that they dislike it.

Procedure of HEC

A Classbook is composed of a series of problems and readings. In the 'problem', all students or pupils must expect a certain result and see their expectation was right. The problem consists of four steps: problem statement, expectation, discussion, and experiment (Itakura, 1967).

In the problem statement, all procedures for conducting the experiment are given. The teacher sets up the experiment as instructed in the statement and explains it to the students. When students understand what is being asked, they choose their expectations of the result of experiment.

The expectation should be chosen from multiple given options. At the beginning of the lesson, the students may choose their expectation based on their intuition without any specific reason, as they have not studied the subject yet.

The teacher requests the students to raise their hands for the option they choose, counts how many students have chosen the option, and writes the numbers up on the board. The teacher asks the students why they have chosen their option. An open discussion should be conducted if needed. After asking the students if anyone wants to change his or her expectation, the teacher conducts the experiment.

The teacher should confirm what option is correct, not explaining why this result occurred and goes on to the next problem. Since people often interpret experimental result to favour themselves, teacher should not explain until the students have acquired a true understanding of scientific concepts. A number of experiments is needed to teach each law or concept in the HEC.

When almost all students have acquired a scientific law or concept, the law or concept is explained in detail through the reading in the Classbook, which often contains the episode within the history of science.

All of this occurs in the Classbooks.

THE CLASSBOOK 'SPRING AND FORCE'

'Spring and Force'

Over 50 Classbooks have been published; these cover not only physics and chemistry but also social science. We introduce the classical Classbook 'Spring and Force' which aim to teach statics published in 1967 (Itakra, 1967).

As has been mentioned, Classbooks contain a number of problems and readings. The one for 'Spring and Force' consists of almost 40 problems and readings and is over 60 pages long. For this reason, we cannot describe all of it here, only being able to introduce it briefly.

Aim of 'Spring and Force'

'Spring and Force' teaches the static concept of force. The intuitive concept of force acquired in daily experiences is based on the sense of human force and ad hoc reasoning. However, the scientific concept of force is based on coherent logic. Using various experiments, to create a conflict between the intuitive concept of force and the scientific concept is the aim of this Classbook.

Introduction of the concept of force

Usually, the concept of force is introduced by gravitational force since almost all students today know gravitational force. However, although people are able to understand the concept of force through understanding an equilibrium of forces, it is difficult to teach equilibrium with gravitational force. The force of the human relates to the feeling of exhaustion and tension, so normal force is difficult to understand.

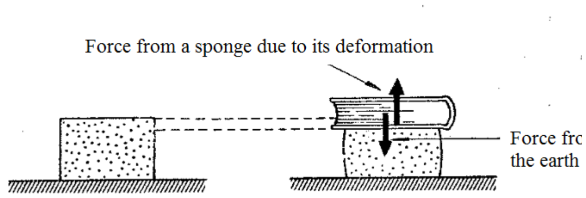
This Classbook introduce the concept of force using the equilibrium of gravitational and magnetic forces.

Introducing normal force by using spring model of matter

After introducing the concept of force, normal force is introduced through the idea that all matter has the nature of a spring.

Since normal forces are often logically introduced through the formal balance of forces, students tend to think that mechanics is a system of sophistry. Even if students can answer correctly on a paper test, they do not believe it in their minds. To render the concept comprehensible, normal force is introduced using a model of matter as a spring. To make this idea concrete, students are instructed that even very strong springs will be deformed by a little force and that a deformed sponge under a book will produce force due to its deformation, as described in this Classbook. (Figure 5a).

The fact that even a desk will be deformed by a small force, since it is composed of atoms, is described in the reading. Students thus realize the concept of normal force themselves (Figure 5b).



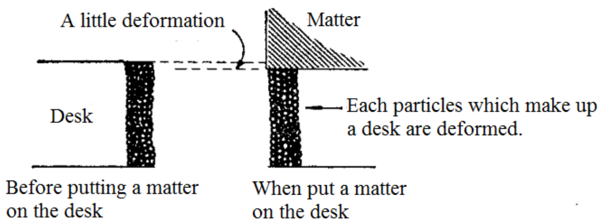
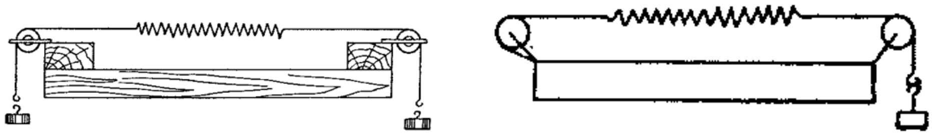


Figure 5a. A book on the sponge **Figure 5b Deformation of the desk**

Experimental conflict between the scientific principle and the intuitive idea

Students accept scientific concepts through problems that lead to conflict between the intuitive idea and scientific logic. One of these problems presented in this Classbook is given in Figure 6.

[Problem] A spring is extended by two weights hanging on both of its sides. If we fix one side of the spring and hang a weight on the other side, how far will it be extended?



i. half the length

ii. the same length

iii. double the length

Figure 6. Classbook Problem - Spring extended by two weights or a weight.

In this problem, most students choose i. Since the weights are reduced by half, it is natural to expect that the length of the extension of the spring will also be half. However, the result of this experiment gives ii. Using such experiments whose results dramatically conflict with intuitive concepts, students can learn the effectiveness of the logic of science over intuitive ideas.

EVALUATION

Result of the final test

As noted, the Classbook under discussion consists of a number of problems. We have only briefly introduced part of it. To go through the whole of this Classbook, 12–13 class hours are needed (a class hour is 45 minutes). According to Itakura's thesis, a final test, made by another researcher, which was used to evaluate their (another researcher's) lessons was used. In the researcher's report, the average of the final test for students taught by their lessons was 46/100. However, the averages on the final test after the HEC lessons was 87–97/100 (Itakura, 1967).

Students' motivation

In HEC, the result of questionnaire determining whether the class was enjoyable was given more value than the results of the final test. Even if the students acquired correct scientific knowledge, this would be meaningless if they did not enjoy learning. The students were thus asked for their evaluation of their degree of enjoyment of the class.

Degree of enjoyment

5. Very enjoyable

4. Enjoyable

3. Neither enjoyable or not.

2. Boring

1. Very boring.

If over a half of students answer 4 or 5, and few answer 2 or 1, the lessons are judged to have succeeded. For Itakura's work in 1967, over 90% of students chose 5 or 4 (Itakura, 1967).

CONCLUSION

We have briefly introduced the basic theory for HEC and the classical Classbook 'Spring and Force', developed in the early days of Itakura's research. Cognitive study of scientific knowledge has been conducted systematically around the world, beginning in the 1980s. Lessons have been improved using this cognitive research. Some of the results are similar to HEC.

However, one special feature of HEC remains the concept of the Classbook. The theory of HEC is little known outside of Japan, because the basic literature for HEC has not been translated into English.

Our colleague is preparing to publish an English translation of Itakura's thesis this year. We expect that HEC will attract attention outside of Japan.

New Classbook that introduce dynamics are in development. We hope to present these it in the future.

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