

# A Communicative CLIL Science Course for Engineers

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### Goal

Deliver a communicative CLIL (content and language integrated learning) science course to 2<sup>nd</sup> year materials science and applied chemistry students.

### Background

English Medium Instruction has been growing in Japan over the last decade, largely as MEXT has pushed for Japanese universities to become "more global": delivering graduates who can function in an English-speaking environment, and additionally making those universities more attractive to international students. A lot of focus has been on large universities, but many smaller universities have begun adopting EMI to some extent to satisfy MEXT requirements. EMI classes in such universities will naturally be of a different character to those in top-flight institutions. Students will not have as good an ability in English, may have less self-confidence, and will find learning about and communicating about the studied subject very challenging. To account for these issues, a EMI course with a communicative focus was designed, as communication in lower-level institutions is still neglected, despite its key role in active, engaged learning (Dornyei, 1998). The course is also aligned with the core points of communicative activities (Brandl 2009).

### Implementation

Instructor-produced articles were the main materials of the course. Due to Covid, the class was conducted by Zoom, which impacted the communicative aspects somewhat. Comprehension checks and written work were moved to Google Forms.

### Course Overview

Topics introduced concepts slowly at first, so as to not overwhelm the students. Topics covered two lessons

**Topic 1** Experiments. Scientific instruments, how we “see science”, are introduced. “Natural experiments”, those we do in our everyday lives, introduce the Scientific Method.

**Topic 2** Numbers, Symbols, and Graphs. Students learn to read numbers, compare data, say and use mathematical and scientific symbols, and talk about common graphs.

**Activity 1** Three Scientific Challenges. Students prepare three paragraphs on scientific challenges of the next 50 years, shared them in class, and reported on one challenge from a partner.

**Part 1: States of Matter**

In the universe, we can observe many states of matter. We have the normal solids, liquids, and gases that make up our world, but we also have some strange states of matter – like plasmas and Bose-Einstein condensates.

We know how matter changes from one state to another: we add or subtract energy, the temperature changes, and the matter changes state. This is shown in Figure 1.

Adding energy, i.e. heating up matter, we usually use the following:

Solid (+energy)	→	Liquid (+energy)	→	Gas (+energy)
(Melting)		(Evaporation)		

Subtracting energy we see:

Gas (-energy)	→	Liquid (-energy)	→	Solid (-energy)
(Condensation)		(Freezing)		

Figure 1: Changes of State

We can see how the normal states of matter are organized in Figure 2. Solids are made up of atoms or molecules which are held in a definite shape. In liquids, the atoms or molecules are not held firmly, and so can move around a little. In gases, the matter is not held at all, and so atoms and molecules are free to move anywhere.

**Part 2: Phenomena**

Communication is something we can observe. In Figure 3 we see some phenomena related to changes in states of matter.

Changing from a solid to a liquid is melting, and from a liquid to gas is evaporation. And when a gas cools to become a liquid it is condensation, and a liquid cooling to become a solid is freezing.

**Part 1: Experiments**

Back in Topic 2 we talked about numbers and graphs. This was because graphs are a good way of showing data (numbers). The numbers shown in graphs are related, as we see in the graph of temperature vs. year (Fig. 1). Each year has a linked temperature.

Figure 1: Central England Temperature 1750 - 2010

We also saw other graph types in Topic 2, and some of these, like the exponential rise (Fig. 2), can be described by equation.

This graph rises slowly at first, and then begins to rise more quickly.

It can be described by an equation, the exponential function:

$$f(x) = 2^x$$

Figure 2: Exponential Rise

$f(x)$  is the Y-axis, and so for each value of X (1, 2, 3, etc.) Y is  $2^1$  (2, 4, 8, etc.). As you can see from the graph, this equation can reach very big numbers.

Of course, scientists have an official name for the final out effect. It is *exponential*.

These are only a few of the strange phenomena that make science so interesting. It shows what other strange things will be found by science in the future!

How do you say the equation below?

$$f(x) = X^3$$

- ☐ f of x equals 2 to the power of x
- ☐ f of x equals 3 to the power of x
- ☐ f of x equals x to the power of y
- ☐ f of x equals x to the power of 3

### Course Plan

Fundamental English for Materials Science (FEfMS) is a mandatory, formerly elective course. Students are 2<sup>nd</sup> year Materials Science and Applied Chemistry students. One hundred and nine students were enrolled in this class.

Classes are science focused, constructed to gradually introduce scientific concepts and also fit the solutions-oriented philosophy of science. Thus puzzles and critical thinking were a key part of the course. Almost all classes had opportunities for students to communicate, from short exchanges at the course start, to significant discussions towards the end.

**TOPIC 1: EXPERIMENTS**

Please read the article below at least twice. The first time, do not use any dictionaries, and just use understanding. The second time, it is to do so for difficult words (please, children, with "I did not use a dictionary" or "I used a dictionary" website). Note: words are important, and you may have to look them up in a dictionary.

**Scientific Instruments: Seeing Science**

People have always been asking questions about the world: "Is the world round?" Why do people get sick? Do things grow and plants around us? How can we answer these questions? For many questions, we can use experiments to give us an answer.

Some questions can't be answered by looking clearly at a problem: observing it. For example, if we want to know how deep a hole is, it will eventually go below the horizon. This shows that the world is not flat. It is round.

If your graph was not good, maybe you could use the right graph below the horizon. However, most people would need help – an optical instrument, like binoculars. Scientific instruments can help us do experiments.

In the past, when people got sick, some people thought it was because of magic. Other people thought it was "bad air". One thing was true: when people got sick, we could not see what was making them sick. A scientific instrument was needed to see how people were getting sick.

This instrument was the microscope. Antoni van Leeuwenhoek, a Dutch scientist, made his own powerful microscopes. Using one of his microscopes, in 1676 he discovered bacteria, which made people sick. His discovery enabled people to start looking at how people really got sick.

However, some questions cannot be answered by science. We do not have scientific instruments that can observe photos, so science cannot answer questions about growth. Many scientists say that something cannot be observed, it cannot exist.

Experiments are the most important thing in science. They help us answer questions about how things work in the world, but without the right instruments, most experiments cannot be done.

**Which is true? \***

Steel	Breaking Load(MPa)
AB	230
CD	460
EF	690

Table 1: Breaking Load

- ☐ AB's breaking load is three times EF's.
- ☐ EF's breaking load is 1.5 times AB's load.
- ☐ EF's breaking load is 150% greater than CD's load.
- ☐ AB's breaking load is 1/3 of CD's load.

**Part 1.6: Taking About Graphs**

So, how do we talk about graphs? Looking at the example above, should we say "straight, straight, straight, up, up more...up?" We could do that, but it would make for a very boring presentation.

For a line graph, the line is a "thing", so we can call the line "it". Our reference points are the x and y axes. So, looking at the graph above, we could say:

"The line is almost flat until x=6, then it rises, then it drops sharply to a point at x=8. It drops sharply again, but with a shoulder just after 8. Becoming flat again at x=9."

For pie charts and bar charts, we can use similar English to that for describing tables (See Topic 2a: Numbers).

Looking at Figure 2, we can say: "The biggest segment is over 2.5 times as big as the next biggest segment" and "The smallest segments are only 2% of the total."

For Figure 3, we can say things like: "Gas is only 1/20 of the size of Brown Coal" and "Gas is over 100 times bigger than Hydrogen".

However, for the graphs we need more words to help us describe them. On the next page is a table of graph features which should help you describe scientific line graphs.

**Part 1.7: A Very Exciting Mission**

On December 13<sup>th</sup>, 1998, a space probe was launched from Cape Canaveral in the United States of America. Its target: Mars, the fourth planet from the Sun.

The rocket carrying it, a Delta II, used over 400,000 pounds of thrust to launch the 2.1 meter tall, 6-foot wide probe from the Earth and set it on a course for Mars.

For 10 months, the probe circled on its journey to the red planet. As the probe entered Mars, everything seemed fine as the 438 kilogram probe. Computers, power, communications, and propulsion were operating at 100%.

At 9 a.m. on the 23<sup>rd</sup> of September 1998, the probe folded away its solar panel, and turned to fly to the 485-meter rocket engine. It did this to slow down, so it could enter orbit around Mars.

At 10:05 a.m. communication with mission control suddenly stopped. They tried hard to restore contact between Mars and Earth. Finally, after many attempts, the probe was declared lost on September 29<sup>th</sup>.

Why was it lost? Investigation discovered that the probe's rocket engine used pounds to control rocket power. However, mission control used newtons to control rocket power. To see how this caused the problem, look at the simple conversion equation below:

1 pound = 4.45 newtons

**Topic 3** Units and Errors. Topic was introduced by a story about the loss of a multi-million dollar space probe due to a maths error. A short discussion on space exploration and money followed.

**Topic 4** Matter and Phenomena. The many states of matter, and the strange phenomena of matter were explored, from freezing hot ice cream, to bumpy asteroids.

**Activity 2** Writing the introductory and concluding paragraphs for an teacher-provided essay on global warming.

**Student Output** The majority of comprehension questions were correctly answered, but for mathematical questions, some were challenging. Graph questions were well done, as were most of those on matter and phenomena. Questions on equations were mainly well-answered.

Student preparation for discussions and essays were easy to understand, reasonably well-formed, and scientifically valid.

### Student Perceptions

Students were given a Google Forms questionnaire at the end of the course covering the areas of English Skill Improvement, Course Opinions, and Topic Opinions. Most questions were Likert-scale, with 1 signifying total disagreement, and 5 signifying total agreement. Other questions involved topic ranking. The results are given in the tables below. All numerical values are medians of the Likert results, n=78.

Course Qs: Course Progression	
As course progressed, new article understanding increased	3.7
As course progressed, English nervousness decreased	3.3
Discussion skills improved as course progressed	3.5

Topics: General	
Prefer science English topics to general English topics	3.5
Course topics professionally useful for me	3.8
Course topics professionally interesting for me	3.8

Topics: Most Interesting (n=58)	Topics: Most Useful (n=58)
1 T4: Matter & Phenomena	1 T2: Numbers, Symbols, & Graphs
2 T5: Equations & Life	2 T3: Units & Errors
3 T1: Experiments & Scientific Method	3 T4: Matter & Phenomena
4 T2: Numbers, Symbols, & Graphs	4 T1: Experiments & Scientific Method
5 T3: Units & Errors	5 T5: Equations & Life

Course Qs: Impact of Stdnt Science Knowledge (SK)	
SK helped me guess meaning of difficult words	3.7
SK helped me guess article's meaning	3.8
SK helped me learn English words	3.7
SK helped me understand English sentences	3.8
SK helped me understand English articles	3.8

Course Qs: Student General	
I had interesting discussions with my classmates	3.4
I learned a lot from my classmates	3.4
I learned new scientific knowledge	3.9
I want to study English more after this course	3.7
Class discussion was professionally relevant	3.7
English is professionally relevant to me	4.0
I tried to use English a lot in this course	3.6
I used translation software a lot in this course	2.6

English Skill Improvement	
Listening	3.5
Speaking	3.3
Reading	3.7
Writing	3.4
Communications Skill	3.5

Areas of note are in *impact of science knowledge; communications skill, reading, and listening improvement; new article understanding; and the students' professional opinions* on the course and English. It is also noteworthy that the two most difficult topics were also the two most interesting topics, and also that the two most useful were the two least interesting.

### Final Points

The course was originally intended to be given face-to-face, with much more interaction possible between students, based on Tohoku University's Prepare, Discuss, React (PDR) Method. Aspects of the PDR method were, however, incorporated in the discussions. It is to be assumed that the communications skill would have increased under these circumstances, with related increases in listening and speaking. Some students groups also failed to participate in discussions, but these were less than 10% of the students enrolled.