

Development and Practice of “Air Pollution” Educational Material Unit Aiming at Education for Sustainable Development (ESD)

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Abstract

We have developed an educational material unit “Air Pollution”, focusing on air pollution control measures and changes of production processes in chemical industries in light of Green and Sustainable Chemistry (GSC). The unit includes worksheets, references and a “Study History sheet” (SH sheet) based on one page portfolio assessment. Upper secondary school students eagerly conducted individual investigation activity. The “Air Pollution” unit is effective for students to learn the GSC approach and to develop scientific attitudes as well as a sense of trust towards science and technology.

Key words : ESD, GSC approach, educational material unit, one page portfolio assessment, science education, secondary education

Introduction

How do students view science classes? In Japan, Surveys of the Educational Curriculum 2001 (NIER report, 2003) have found that science is the most popular among five subjects (science, math, social science, Japanese and English). With regard to the question of whether the study of science is important, however, although a majority of both elementary and lower secondary school students consider it to be important, the percentage is the lowest among the

five subjects. Turning to questions relating specifically to science classes, three out of four lower secondary school students said that they agreed with the statement “The study of science is necessary to preserve nature and the environment,” while in the upper secondary school classes, two out of three upper secondary school students agreed with the statement. Thus majorities recognized the need for the study of science. However, only half of the elementary school students and one in three of the upper secondary school students agreed with the

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statement “If I study science, it will be useful in daily life and when I go out into society.”

In Japan low and declining interest in science has recently become an issue. Even after viewing the results of various studies, it is not clear what students think about the significance of science classes. One thing that is clear is that they recognize that science is needed to protect the environment. This suggests that teaching environment-related matters in science classes may increase the interest in science.

2005 marked the beginning of the United Nations Decade of Education for Sustainable Development (ESD). We were encouraged to develop an educational material unit aiming at ESD. On the basis of the product materials of “Developing Teaching Materials for Science, Technology and Society” project (Matsubara & Watanabe, 1991), we have developed an educational material unit “Air Pollution” in light of Green Chemistry (Anatase & Warner, 1998) or Green and Sustainable Chemistry (GSC). These materials cover the subject of air pollution control measures and deal with the transition to GSC-compatible processes in chemical industries.

GSC deals with principles and methodologies that prevent the generation of the pollutants themselves rather than dealing with pollutants after they have been produced. We feel that incorporating the GSC approach into educational materials is important from the

standpoint of making chemistry education meaningful by not only informing students about GSC but also creating opportunities to get students to think about science as it ought to be.

Students need not only to learn about science but also to develop scientific perspectives and scientific attitudes including the capacity to judge and make decisions regarding scientific and technical matters. The GSC approach can serve as a basis for judging and making decisions. In order to encourage and nurture the ability of the students to make judgments for themselves and make their own decisions, we adopted investigation activity by each student.

“Air Pollution” educational material unit (Condensed Version)

The “Air Pollution” unit consists of worksheets, references and a Study History sheet (SH sheet). The original version of the unit required 6-8 lesson hours or more. In an effort to reduce the burden, we have prepared a condensed version that allowed the unit to be practiced in three lesson hours.

Table 1 shows the composition of the worksheets (WS1, 2 and 3). Students fill out the blanks of the worksheets referring to the references delivered as handouts. Worksheets 1 and 2 present case studies to learn about air pollution control measures and process

Table 1 Composition of the worksheets of the “Air Pollution” unit (condensed version)

WS1: The problem of hydrogen chloride caused by the old way of manufacturing Na_2CO_3 and resolving the problem of hydrogen chloride pollution by the ammonia soda process
WS2: The problems of sulfur oxides and nitrogen oxides and efforts to find solutions in the cases of metal refineries and power plants in Japan
WS3: Summary of WS1 – WS2 and GSC

Note: WS = worksheet

changes of chemical industries. Worksheet 3 summarizes the contents of WS1 – WS2 and explains GSC.

Worksheet 1 describes the Leblanc process, the old method used to manufacture sodium carbonate. While this method thrived due to the demand for use in the textile industry as a result of the Industrial Revolution, the method produced hydrogen chloride pollution. The first measure to deal with this problem was to disperse the substance into the atmosphere or dump it into rivers to dilute it, but this only resulted in the pollution being spread over a wider area. The problem was resolved by collecting the substance to market it as chlorine.

Worksheet 1 also deals with the ammonia soda process, the method used to manufacture sodium carbonate. The change from the Leblanc process to the ammonia soda process was a transition to a method that did not generate the environmentally polluting hydrogen chloride produced by the Leblanc method. This represents a shift from dealing with pollution after it has occurred to a process that does not produce that pollution -- in other words, a shift to GSC.

Worksheet 2 deals with sulfur oxides. Sulfur oxides were produced in the copper refining process and by burning oil. At first, the problem was dealt with by dispersal and dilution, but in most cases this simply resulted in the pollution becoming spread over a wider area. Subsequently, flue gas desulfurization and crude oil desulfurization technologies were developed, and the combination of these two technologies has enabled Japan to almost completely eliminate the discharge of sulfur oxides into the atmosphere. This change, too, represents a transition to GSC.

Worksheet 2 also deals with nitrogen

oxides. Most of the nitrogen oxides can be removed by flue gas denitrification and other methods, but these substances cannot yet be eliminated completely. This provides an opportunity for the students themselves to think of ways of accomplishing this goal.

Worksheet 3 explains the GSC approach on the basis of the definition of risk, i.e.

$$\text{Risk} = \text{Hazard} \times \text{Exposure} ,$$

and the 12 principles of green chemistry (www.epa.gov). The best way of dealing with environmental pollution would be to change from a process of resolving the air pollution problem to a process that does not produce air pollutants. The 12 principles are encouraging researchers to change their perspective and conduct research in harmony with GSC. Students learn that there are increased opportunities for not only scientists and engineers but also the general public as well to participate in consensus forming regarding technical innovation in a desirable direction in the future.

Study History sheet

In order to evaluate and improve the "Air Pollution" unit, we prepared a Study History sheet (SH sheet) using one A3 size sheet based on the one page portfolio assessment method (Hori, 2003). Students fill out individual SH sheet whenever they finish each worksheet (WS1, 2 and 3). The SH sheet is designed to get the students themselves to become aware of how their knowledge and opinions have changed as a result of the lesson.

The SH sheet is made up of three sections. The first section consists of before and after study boxes. First of all, students write three

sentences in the before study box using a key word “Air pollution.” After finishing all worksheets, students write three sentences in the after study box using the same key word. Comparing the sentences written by students before and after study enables the students themselves to recognize the changes produced by the lesson. The second section has three summary boxes for the worksheets (WS1, 2 and 3). After filling out each worksheet, students summarize the contents of the worksheet in each summary box. As each box is not large enough, students have to select words and sentences of the summary, which is one of the purposes of this section. Finally in the third section, students write looking-back impressions on their achievement and give their views on the unit.

Analysis of the SH sheets filled out by students was useful for making the educational materials and the SH sheet suitable for use in upper secondary schools as well as improving teacher's instruction. Owing to the SH sheet, the individual investigation activity has become plain and meaningful.

Actual use of the “Air Pollution” unit

During the past three years (2002-2004), the original version of the “Air Pollution” unit was practiced at six upper secondary schools to the extent possible in each school (total approximately 200 students). The “Air Pollution” unit was used in upper secondary school Chemistry I (ordinary chemistry), as well as during Period-for Integrated Study and in Chemistry II (advanced chemistry). In this effort, the unit was used together with textbooks and supplementary educational materials as well as chronological tables and other educational materials that had been prepared in advance.

The condensed version of the “Air Pollution” unit has been used at five upper secondary schools since 2004 (total approximately 200 students). Practicing the condensed version during the chapter on inorganic substances enabled quite similar results as with the original version up to now to be obtained.

Student responses to the “Air Pollution” unit

Here is a typical response from a student of an upper secondary school, showing an increase in the amount of words that the student wrote after study as compared to before study.

Before study

- Air pollution means making the air dirty.
- Car tail exhaust or fumes from factories cause air pollution.
- Air pollution leads to destruction of the ozone layer.

After study

- People were so enthusiastic to develop science and technology that they paid little attention to nature. Consequently air pollution was brought about.
- Control measures against air pollution by pollutants such as SO_x and NO_x resulted in dispersal of the air pollution. Then the resolution shifted to a way that did not produce pollutants.
- After these experiences green chemistry has been promoted that does not exhaust or produce pollutants and reduces the hazard to a harmless level.

The following examples show typical features of the looking-back impression.

"I knew little about air pollution before the lesson. I never thought that air pollution existed since a long time ago and various control measures were taken. Through the lesson I learned what caused air pollution, what influence had the air pollution on human beings and living things and what kinds of measures were taken to solve the problems. It was impressive study for me."

"Before the lesson, I didn't know about air pollution so much. It was the first time to learn that ammonia soda method that I studied already played an important role in the air pollution control measures. I felt that chemistry closely correlates with environmental issues."

"I was strongly impressed by knowing that air pollution has a long history more than a hundred years and that scientists have tried to improve the situation by trial and error since more than a hundred years ago. In order not to accelerate air pollution, I thought I should take action with a positive idea."

"I never earnestly thought of air pollution before. As I learned various causes and measures, I can recognize how serious the problem was. I expect that green chemistry contributes to reducing the risk not only of air pollution but also of various environmental issues."

"We should face to air pollution hereafter. We need to develop our scientific knowledge on air pollution and think about what we can do by ourselves in our daily lives."

It became clear that there are many students with no detailed knowledge of the environment and environmental issues. In the looking-back responses, the following points are representatives: that air pollution measures have been implemented by many people, that knowing the historical facts of air pollution is instructive, that the image of chemistry or science has changed, e.g. "Chemistry is great", that GSC should be promoted and that the concern over environmental issues is provoked with the desire to take action against the problems.

The following looking-back impression and views on the unit (the original version) show the importance of considering both advantages and disadvantages:

"I've heard a lot about air pollution and environmental pollution and so on from newspapers and TV and in school. But I knew almost nothing specific about what actually causes pollution and what should be done about it. Learning about it in this lesson deepened my understanding.

Moreover, I had only heard about the affirmative aspects of science and technology, but in this lesson I was able to consider the negative aspects. At the same time, by learning about the process by which these negative aspects were overcome, I was able to consider the potential of even those things for which we can now only see negative aspects. In this way, I was able to think about the potential of further advances in science and technology.

This lesson showed me science and technology from a completely different perspective, and it enabled me to think about them in a different way."

The first part of this response is a common reaction after studying educational materials like these. The next section indicates that learning about both the advantages and the disadvantages and the process of resolving the disadvantages helped the student to understand the position of scientists and engineers, and that science and technology have the potential to improve the environment. This shows that enabling the students to obtain information about not only affirmative aspects but negative aspects as well enables them to fashion opinions that can lead to making their own judgments and making their own decisions, based on a knowledge of advantages and disadvantages, and moreover that a knowledge of the existence of negative aspects and the process by which these have been overcome leads students to consider the development of science and technology in the future and cultivates an affirmative attitude toward the value of science. In short, this example shows that enabling students to obtain the plain facts gives them a deeper understanding of science and technology.

Effects of implementation of the “Air Pollution” unit

The results of the practices of the “Air Pollution” unit at upper secondary schools were that the unit caused the students to become increasingly interested as the lessons went on, and they came to put a great deal of effort into their investigation activity. In the student reactions regarding how they felt about the unit, the responses were favorable with regard to not only the educational materials but to science and technology in general.

The responses also showed that students

had only a vague knowledge of environmental issues and solutions. Some students even thought that environmental problems were being resolved by establishing laws and had no idea that there were scientists and engineers working to resolve these problems. Most students, however, discovered through historical facts that scientists and engineers work to develop methods that produce as little harm as possible. This resulted in a sense of trust towards science and technology. The student reactions showed a sense of anticipation with respect to scientists and engineers, as well as the sense that there is something that even the students themselves could do, and the desire to get involved.

Conclusion

The “Air Pollution” educational material unit is effective for upper secondary school students to conduct enthusiastic investigation activity and develop favorable attitude towards science and technology. Enabling students to obtain information about historical facts including the efforts of scientists and engineers and the GSC approach gave them confidence in science and technology and stimulated to develop scientific perspectives and attitudes.

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