TSC-4064-2

Waste Management

Path:

Environmental Science and Technology

Science and the Environment

Québec

TSC-4064-2 Waste Management

INTRODUCTION

The course entitled *Waste Management* is aimed at enabling adult learners to function effectively in learning situations from the *Research* and *Expertise* families that involve the production and elimination of waste generated by the transformation of natural resources and their impact on the environment.

In this course, adult learners will study environmental issues or technological applications involving waste and seek answers or solutions to related problems. They will acquire knowledge about chemical changes, nuclear transformations, the physical properties of solutions and the organization of matter. This knowledge, combined with the knowledge they will acquire in their study of *The Technological World* and *The Earth and Space*, will help them understand the technological processes that can limit the contamination of the lithosphere, hydrosphere and atmosphere. In addition, by acquiring knowledge related to *The Living World* (e.g. ecotoxicology and the concept of ecological footprint), they will become more aware of the impact of pollution generated by waste resulting from the transformation of natural resources.

By the end of this course, in situations involving the production and elimination of waste generated by the transformation of natural resources and their impact on the environment, adult learners will be able to:

- ✓ analyze the impact of domestic and industrial waste on the environment
- ✓ analyze a technological application related to the production or elimination of waste generated by the transformation of natural resources
- ✓ discuss the effects of certain chemical compounds or nuclear waste on the environment
- ✓ explain the formation of chemical compounds using the periodic properties of the elements
- ✓ plan a simple experiment dealing with the physical properties of solutions or chemical changes
- ✓ follow an experimental procedure that deals with the physical properties of solutions or chemical changes
- ✓ write a report on an experiment related to the physical properties of solutions or chemical changes
- ✓ take a stand on the effects of human activity on the biosphere or on the ways used to limit them

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to scientific or technological problems	Competency 2 Makes the most of his/her knowledge of science and technology	Competency 3 Communicates in the languages used in science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Puts applications or scientific and technological issues in context ▪ Analyzes an application or an aspect of the issue from a scientific point of view ▪ Forms an opinion about the issue	▪ Interprets scientific and technological messages ▪ Produces scientific and technological messages

PROCESSES

The investigative processes enable adult learners to examine issues, solve scientific problems and study applications. The following are the steps in an investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate methods for this course are the experimental method, modelling, documentary research and the observation method. It is during hypothesis testing that these methods become distinguishable. Section 3.5 and Appendixes 1 to 3 present these investigative processes with their respective characteristics.

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course TSC-4064-2 allows for all the cross-curricular competencies to be put into practice. Some of them, indicated in grey shading in the table below, are especially targeted in the sample learning situation that will be presented in the last part of the course.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC COMPETENCIES

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

❖ The Living World	
General concept: Ecology The ecological footprint is a tool for evaluating the practical impact of human activity on ecosystems in order to provide for the balanced management of resources. It corresponds to the biologically productive surface of the Earth necessary to ensure the standard of living of an individual or a population. Ecotoxicology is the study of the long-term effects of certain chronic pollutants on ecosystems. While a good many contaminants may degrade naturally, others (e.g. phosphates and mercury) accumulate in ecosystems, living organisms, waterways, lakes and ponds. The toxicity of a contaminant depends on its concentration, the characteristics of the environment in which it is released, the nature of the organisms with which it comes into contact, and the duration of exposure. The toxicity threshold is the minimum quantity of contaminant (in milligrams per kilogram of the organism's mass) that will produce a harmful effect on an organism. **Note:** *Adult learners are only required to perform a qualitative analysis of the toxicity of the environment being studied, based on data made available to them.*	
Compulsory concepts	**KNOWLEDGE TO BE ACQUIRED**
Ecological footprint	• Describes the concept of ecological footprint • Explains the usefulness of the concept of ecological footprint
Ecotoxicology: - contaminants	• Defines a contaminant as an agent that causes changes in the physical, chemical or biological properties of an environment or an organism
- bioaccumulation	• Describes bioaccumulation as being the accumulation, in an organism, of a contaminant originating in its environment or food • Explains bioaccumulation in trophic levels (bioamplification)
- bioconcentration	• Defines "bioconcentration" as a special case of bioaccumulation where an organism accumulates a contaminant while in direct contact with its habitat (sources other than its food)
- toxicity threshold	• Defines the toxicity threshold of a substance as the minimum quantity of a substance that can produce a considerable harmful effect on an organism • Describes factors that influence the toxicity of a contaminant (e.g. concentration, characteristics of the environment in which it is released, nature of the organisms with which it comes into contact, duration of exposure)

❖ The Earth and Space

General concept: Biogeochemical cycles

Phosphorus occurs mainly in rocks and is introduced into biological systems through natural erosion processes. Decomposed biological waste can accumulate in large quantities in soil and sediment. The phosphorus cycle is affected by the use of fertilizers, as well as by household and industrial wastewater containing detergents and phosphates.

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Phosphorus cycle	• Describes the changes related to the circulation of phosphorus (e.g. erosion of rocks, degradation of fertilizers)

General concept: Lithosphere

The lithosphere contains a wide variety of mineral resources essential to the development of societies, including metals, industrial minerals and construction materials. The use and transformation of minerals, however, have an impact on the environment. Contamination by persistent organic compounds or heavy metals can modify the physical, chemical and biological properties of the soil and affect its fertility. Soil pollution also varies according to the atmospheric deposits resulting from industrial and agricultural activity. In addition, these resources exist in limited amounts, hence the growing need to take another look at residual materials and recycling in general.

Some agricultural and forestry practices reduce the soil's ability to promote the growth of healthy vegetation. Overcutting exposes more soil to erosion and strips the topsoil of essential minerals and microorganisms. The buffering capacity of the soil is its ability to limit pH variations, which enables it to postpone the consequences of contamination. Its measurement is an indicator of the soil's fertility. For example, the gradual acidification of the soil resulting from acid rain gradually reduces its buffering capacity and leads to the introduction of nutrients or heavy metals into the system.

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Contamination	• Names contaminants found in the soil
Soil depletion	• Defines the concept of soil depletion • Explains how human activity contributes to soil depletion
Buffering capacity of the soil	• Defines the buffering capacity of the soil as its ability to limit pH variations • Explains the advantages of a soil with good buffering capacity

❖ The Earth and Space (cont.)

General concept: Hydrosphere

An aquatic environment becomes polluted once its balance has been permanently modified either by the introduction of vast quantities of toxic substances or by an increase in water temperature. When pollutants accumulate, they can cause a decline in populations of more fragile species, alter their physiological abilities or degrade the quality of the water to such an extent that it becomes unsafe for drinking. Other pollutants, such as plastics, metals and some pesticides, are not biodegradable, or barely so; these substances harm the organisms that ingest them. The effects of the different pollutants on aquatic environments depend on the nature and concentration of the pollutant, as well as on the characteristics of the ecosystem. An excessive concentration of phosphates or nitrates, for example, may cause the proliferation of cyanobacteria. In some cases, this can result in the production of neurotoxins harmful to living organisms.

Eutrophication is a stage in the natural evolution of a stagnant body of water. The process intensifies in the presence of excessive amounts of nutrients, particularly nitrogen and phosphorus compounds, which accelerate the growth of algae and other plant forms. This increase in biomass, combined with high water temperatures, causes a decrease in the amount of dissolved oxygen and limits the self-cleaning ability of the body of water. This form of degradation is related to agricultural, household and industrial activities (e.g. animal waste, agricultural runoff, wastewater).

Compulsory concepts	**KNOWLEDGE TO BE ACQUIRED**
Contamination	• Names contaminants found in water
Catchment area	• Defines a catchment area as a territory surrounding a water system • Describes some of the impacts of human activity on the waterways in a catchment area
Eutrophication	• Explains the natural process of the eutrophication of a body of water • Explains how human activities accelerate the eutrophication of a body of water

General concept: Atmosphere

The different substances emitted during the combustion of fossil fuels have harmful effects at the local, regional and planetary level. Oxides of sulphur, carbon and nitrogen are acid precursors; they contribute to the acidification of precipitation. The air can also be contaminated by solid and liquid suspended particles (e.g. dust, pollen, soot, smoke, droplets) that affect the respiratory system. A biome located far away from the emission of gases can become contaminated. Prevailing winds foster the circulation of contaminants in the atmosphere.

Compulsory concepts	**KNOWLEDGE TO BE ACQUIRED**
Contamination	• Names contaminants found in the air
Atmospheric circulation: prevailing winds	• Describes the effect of prevailing winds on the dispersion of pollutants in a given region

❖ The Material World

General concept: Organization of matter

This section examines the properties of the main families in the periodic table and of metals, non-metals and metalloids. This type of classification makes it possible to predict the behaviour of matter. In the periodic table, the elements are classified in increasing order by atomic number. This number designates the number of protons in the nucleus and makes it possible to differentiate among the elements. This classification (with a few irregularities) is based on increasing atomic mass, the relationships between elements with similar chemical properties and the periodicity of certain physical and chemical properties of the elements.

Some atoms of a given element, called isotopes, differ from the others in the number of neutrons they have and, therefore, in their atomic mass. They occupy the same place in the periodic table because they have the same atomic number and the same chemical properties. Isotopes are naturally occurring, but they can also be produced in the laboratory or in industrial settings.

The number of the family in the periodic table indicates the number of valence electrons the element has. Lewis notation represents the valence electrons in an element. It makes it easier to understand the combination of atoms in a molecule. This information enables us to predict certain behaviour by comparing atomic structure with the properties of the elements. The concept of mole and Avogadro's number are addressed to enable adult learners to calculate the quantitative relationships between reagents and products in chemical reactions.

Compulsory concepts	**KNOWLEDGE TO BE ACQUIRED**
Periodic table: - groups (families) and periods	• Locates the groups and periods in the periodic table • Describes the common characteristics of a family (e.g. number of valence electrons, chemical reactivity) • Associates the number of electronic shells in an element with the number of its period
Simplified atomic model	• Represents an atom of an element using the simplified atomic model
Atomic number	• Associates the atomic number of an element with the number of protons it has
Relative atomic mass	• Describes the concept of relative atomic mass
Periodicity of properties	• Describes the periodicity of certain properties of the elements (e.g. chemical reactivity, atomic radius, electronegativity)
Isotopes	• Defines an isotope as the atom of an element where the nucleus contains a different number of neutrons giving the atom a different atomic mass • Defines a radioactive isotope as an isotope that has an unstable nucleus
Lewis notation	• Determines the number of valence electrons in an element • Represents atoms using Lewis notation
Polyatomic ions	• Recognizes common polyatomic ions (e.g. NH_4^+, OH^-, NO_3^-, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}) by their name, their formula or their composition
Nomenclature and notation rules	• Applies nomenclature and notation rules to name a molecule or write the molecular formula for binary compounds
Concept of mole	• Defines the concept of mole • Expresses a quantity of matter in moles
Avogadro's number	• Expresses a number of particles using Avogadro's number

❖ The Material World (cont.)

General concept: Physical properties of solutions

The fact that many substances dissolve in water is essential to understanding biological and environmental phenomena. Aqueous solutions are common in the environment, and their properties are measurable and observable. The physical properties of aqueous solutions vary depending on the nature and proportion of their constituents.

The solubility of a solid or gas is measured in grams of solute per volume of solvent and varies according to temperature. In the *Climate Change* course, adults learned to measure concentration in parts per million (ppm), as a percentage (%) and in grams per litre (g/L). In this course, they learn to measure concentration in moles of solute per litre of solution (mol/L).

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Solubility	• Defines the concept of solubility
Strength of electrolytes	• Qualitatively speaking, associates the strength of an electrolyte with its degree of dissociation
Concentration in mol/L	• Determines the concentration of an aqueous solution (mol/L) • Converts a concentration (g/L, percentage or ppm) into mol/L

General concept: Chemical changes

After studying the concepts of oxidation, acid-base neutralization, combustion, photosynthesis and respiration in the *Climate Change* course, adult learners examine precipitation, decomposition and synthesis in this course. These chemical reactions show that the atoms of different elements and ions have the ability to bond with other atoms depending on their atomic structure.

Stoichiometry is the calculation of quantities of matter (in moles and grams) involved in a chemical reaction.

In a chemical reaction, atoms tend to acquire the peripheral electronic structure of the closest inert gas. This ability to gain, lose or share electrons is determined by the number and arrangement of the electrons in the atoms.

Note: *Stoichiometric calculations are based on the assumption that the chemical reactions are complete. Transition elements are not considered in the study of the different types of bonds.*

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Precipitation	• Represents a precipitation reaction using the particle model
Oxidation	• Associates oxidation reactions with chemical equations in which oxygen gas is one of the reagents
Decomposition and synthesis	• Associates known chemical reactions with decomposition or synthesis reactions (e.g. respiration, photosynthesis, combustion, digestion)
Acid-base neutralization reaction	• Recognizes an acid-base neutralization reaction based on its equation
Salts	• Determines the molecular formula of the salt formed during an acid-base neutralization reaction

❖ The Material World (cont.)

General concept: Chemical changes (cont.)

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Stoichiometry	• Determines the quantity of reagents or products using stoichiometric calculations
Types of bonds: - covalent	• Defines a covalent bond as a bond involving the sharing of electrons • Represents a covalent bond schematically • Identifies molecules containing covalent bonds (e.g. N_2, CO_2)
- ionic	• Defines an ionic bond as a bond involving the gain or loss of an electron • Represents an ionic bond schematically • Identifies molecules containing ionic bonds (e.g. NaCl, NH_4OH) • Associates the presence of an ionic bond with an electrolytic substance

General concept: Nuclear transformations

Changes in matter are considered “nuclear” when they occur in the nucleus of the atom (review the simplified atomic model studied in course TSC-4061-2). During these transformations, the cohesive strength of the nucleons is insufficient to maintain the stability of the nucleus. New nuclei are created (heavier in the case of fusion and lighter in the case of fission or disintegration), particles travel at great speed (kinetic energy) and vast quantities of energy are emitted in the form of radiation. Nuclear energy has enormous potential. However, while radioactive substances have undeniable advantages, their radiation has a definite impact on health.

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Nuclear stability	• Defines “nuclear stability” as the cohesion of the nucleus resulting from the fact that an atom has an optimal number of neutrons
Fission and fusion	• Distinguishes between nuclear fusion and nuclear fission
Radioactivity	• Defines “radioactivity” as the emission of particles or energy by the nuclei of atoms following nuclear transformations • Associates the use of radioactivity with technological applications (e.g. radiation therapy, carbon dating)

❖ The Technological World

General concept: Biotechnology

Decontamination processes involve a series of steps consisting of physical, physicochemical and biological treatments. In certain cases, other treatments are necessary (e.g. addition of a disinfecting reagent, use of ultraviolet radiation, ozonation) when the water ends up in a particularly sensitive area. Biological soil decontamination, wastewater and air purification treatments use plants or microorganisms to degrade various pollutants. The main characteristics of an effective decontaminant include the ability to transform a wide range of chemical compounds, to absorb pollutants and to tolerate toxic substances.

No treatment can fully decontaminate soils.

Compulsory concepts	KNOWLEDGE TO BE ACQUIRED
Wastewater treatment	• Describes the treatments used to decontaminate wastewater
Biodegradation of pollutants	• Describes methods of biodegrading pollutants (e.g. phytoremediation)

2. Techniques

The techniques presented here are grouped in two categories. Many of these techniques require the use of instruments and tools or chemicals. Safety and the use of safety equipment in the workshop and laboratory must be a constant concern for all those using such techniques.

In the Laboratory or Workshop	
Techniques	**KNOWLEDGE TO BE ACQUIRED**
Experimentation	
- Safely using materials and equipment	• Uses laboratory materials and equipment safely (e.g. allows hotplate to cool, uses beaker tongs) • Handles chemicals safely (e.g. uses a spatula and a pipette filler)
- Preparing solutions	• Prepares an aqueous solution of a specific concentration given a solid solute • Prepares an aqueous solution of a specific concentration given a concentrated aqueous solution
- Collecting samples	• Collects samples appropriately (e.g. sterilizes the container, uses a spatula, refrigerates the sample)
Measurement	
- Using measuring instruments	• Chooses the appropriate measuring instrument • Uses measuring instruments appropriately (e.g. volumetric flask, pipette, pH meter)
- Checking the reliability, accuracy and sensitivity of measuring instruments	• Takes the same measurement several times in order to verify the reliability of the instrument used • Carries out the necessary operations to ensure the accuracy of a measuring instrument (e.g. cleans and calibrates a balance, dries a graduated cylinder, conditions a pH meter) • Takes the sensitivity of a measuring instrument into account (e.g. uses a 25-mL graduated cylinder rather than a 100-mL graduated cylinder to measure 18 mL of water)
- Interpreting measurement results (significant digits, measurement errors)	• Determines the margin of error attributable to a measuring instrument (e.g. the error in a measurement made using a graduated cylinder is provided by the manufacturer or corresponds to half of the smallest division on the scale) • Expresses a result with a number of significant figures that takes into account the errors related to the measure (e.g. a measurement between 10.3 and 10.4 cm, taken with a ruler graduated in millimetres, should be expressed as 10.35 cm or 103.5 mm)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course.

Cultural References				
Technical objects, technological systems, processes and products	– Radiation therapy equipment, magnetic resonance imaging, etc. – Petroleum: well, platform, refining processes – Pollutant analyzers: passive diffusion tube, quartz microbalance, beta radiation detector – UV photometric measurement through infrared correlation – Chromatographs, gravimeter, barometer, hygrometer, anemometer – Air exchanger, water softener – Processes for obtaining biofuels (oleaginous, ethyl, gaseous, solid) – Particle filters, antipollution systems on motor vehicles – Smokestack scrubber – Wastewater treatment plant, wastewater purification processes (lagooning or natural filtration using microorganisms) – Drinking water treatment plant, drinking water purification processes (e.g. filtration, ozonation, boiling, distillation, photo-oxidation) – Sorbent barriers, circular brush skimmer, oleophilic rollers (beach), screen (sand) – Physicochemical depollution (dissolution of pollutants): vacuum extraction, injection, flotation treatment, etc. – Biological decontamination: processes using bacteria – Phytorestoration (plant bioremediation)			
Area	**Scientists**	**Community Resources**	**Applications**	**Events**
The Living World	Rachel Louise Carson	Health Canada (Environmental and Workplace Health) Montréal Biodôme Wastewater treatment plants	Environmental protection	
The Earth and Space		Geological Survey of Canada Mining Natural Resources Canada Greenpeace BGS (Brundtland Green Schools) Recyc-Québec	Decontamination activities Observation satellites Global positioning systems (GPS) Regulatory Framework for Air Emissions	Meteorological phenomena Earth Summits
The Material World	Henry Cavendish Svante Arrhenius Sir Isaac Newton Dmitri Mendeleev	Museums of natural science International Union of Pure and Applied Chemistry (IUPAC)	Means of transportation	

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, deal with the waste produced by processing natural resources and with the resulting contamination, as well as with general concepts related to different areas. The following paragraphs contain examples of tasks that could be assigned to adult learners in learning situations involving different combinations of general concepts.

In a learning situation involving the atmosphere and chemical changes, adult learners could determine the impact of different gases on the ozone layer in relation to carbon dioxide (CO_2). They could also illustrate relationships between the composition of air and certain chemical reactions that take place there.

A learning situation could involve the chemical transformation of matter and the contamination of the lithosphere, atmosphere and hydrosphere. In the laboratory, adult learners could analyze the effects of different chemicals on different terrestrial systems or find information about the methods used to deal with problems such as smog, acid rain, the contamination of soil and drinking water, and the bioaccumulation of contaminants.

In a learning situation involving nuclear transformations, the lithosphere, the hydrosphere and the atmosphere, adult learners could analyze the circulation of nuclear contaminants between these different systems or model the circulation of prevailing winds to explain why the contaminants can be found far from their source.

Once they have learned about the biodegradation of pollutants and nuclear transformations, adults could, in a learning situation, take a position on the conceptual, ethical and practical aspects of technological processes that produce nuclear waste, analyze possible solutions to the problem of environmental pollutants or compare and evaluate the quality of decontamination processes.

In the learning situation described below, the main tasks help adult learners develop the first and third competencies. This situation therefore belongs to the *Research* family.

BROAD AREAS OF LEARNING

Learning situations will have more meaning for adult learners if they are related to the broad areas of learning. All of the broad areas of learning are readily applicable to the learning situations for course TSC-4064-2. The example below reflects the educational aim of the broad area of learning *Environmental Awareness and Consumer Rights and Responsibilities.*

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLE OF A LEARNING SITUATION

RECLAIMING TERRITORY

Your municipality is in the news. A group of citizens wants to have a vacant lot decontaminated. Fifty years ago, it was the site of sustained industrial activity. Today, it still contains waste from times past and traces of suspicious chemicals sometimes leach from the soil after a heavy rainfall. The public is concerned. The aim is to have the municipality pay to decontaminate the soil and transform the lot into a soccer field.

To determine the feasibility of the project, the citizens' group asks you to help it identify the contaminants present in the soil.

Your job is to:

- make a list of the substances used or dumped on the site when it was an industrial area
- identify those that are hazardous or toxic
- collect soil samples at different locations and at different depths
- find the best way, given the equipment available, of identifying hazardous or toxic substances in the samples collected
- analyze the samples
- report to the citizens' group on the results of your analyses and your conclusions concerning the nature of the contaminants found and the hazard they represent

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative process involving the experimental method, modelling, documentary research or the observation method. The learning situations also enable adult learners to apply their problem-solving skills and knowledge, and to produce messages.

Adult learners engaged in the process of solving an open problem related to the production or elimination of waste resulting from the transformation of natural resources develop a representation of the problem in question after reading and interpreting scientific and technical messages. They establish a simple experimental procedure or a modelling technique based on the chosen hypothesis, relying on their knowledge of ecology, the physical properties of solutions or chemical changes. They carry out the steps in their plan of action. During these activities, they handle solutions of different concentrations, or adjust the steps in their plan, using the appropriate techniques. In a report, they give an answer that takes their results into account and verify whether their analysis of the results corresponds to their initial hypothesis.

Adult learners studying an environmental issue or technological application related to the production or elimination of waste formulate questions related to the contextual elements presented. They identify the characteristics of the issue or application as they relate to the physical properties of the solutions in question or chemical changes. Using concepts, laws, theories or models, they explain a related issue, illustrate the chemical reactions involved, describe the chemical elements at play and determine the quantity of products and reagents involved. Using their scientific and technological knowledge, they take a stand on different ways of limiting the impact of household or industrial waste on the environment.

EVALUATION CRITERIA FOR SUBJECT-SPECIFIC COMPETENCIES

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Appropriate interpretation of the issue ▪ Relevant use of scientific and technological knowledge ▪ Appropriate formulation of explanations or solutions	▪ Accurate interpretation of scientific and technological messages ▪ Appropriate production or transmission of scientific and technological messages

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