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Fundamental chemistry concepts on environmental pollution: Experts validation of pre-learning questions

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Abstract

The purpose of the research was conducting expert validation on environmental pollution problems based on the fundamental chemistry concepts. The type of research was design and development that involved three experts as validators. Data processing was carried out using SPSS ver.26 through the Kendall test. The values of Asymp.Sig. showed that pre-learning questions were valid in terms of the compatibility of pre-learning questions with indicators of the national curriculum and SDGs, compatibility of pre-learning questions with creative thinking indicators, and clarity of language use. The pre-learning questions were divided into ten indicators. Most of them asked students to describe of how greenhouse gases, heavy metal, and solid or liquid nano-plastic destroy environment. Students explained and wrote the chemical representations of those processes, namely macroscopic, sub-microscopic, and symbolic. Pre-learning questions were valid because they have conducted a curriculum review and the needs analysis. Besides, the creation process also involved teachers who mastered fundamental concept of chemistry and understood the condition of students. The validated pre-learning question is expected to help teachers deliver the fundamental concepts of chemistry on environmental pollution well so that teachers can achieve learning objectives.

Keywords: *Environmental Pollution, Fundamental Chemistry Concept, Pre-learning Questions.*

1. Introduction

All countries in the world basically have a commitment to reduce greenhouse gas emissions in order to achieve sustainable common prosperity for the future of the earth, one of which is by designing the creation of a clean industry program and a zero carbon footprint. [1-4]. Some educational institutions even have special programs to reduce greenhouse gas emissions by inserting sustainable environmental awareness through campus policies. [5, 6]. One effective way to voice greenhouse gas emission reductions is through government regulations or through formal education in the context of socio-scientific issues [7, 8]. But this is a very dramatic thing because the progress of a nation depends on the consumption of energy which usually comes from fossil fuels. Massive consumption of fossil fuels will result in huge greenhouse gas emissions, causing global warming and even climate change, being responsible for sea-level rise, flooding, and other extreme weather [9]. Carbon dioxide gas (CO_2) is a greenhouse gas that has the highest popularity among other greenhouse gases [10, 11]. The gas is produced by household and industrial activities through an oxidation process that not only produces water molecules but also heats energy because the reaction is exothermic [8]. The increase in greenhouse gas emissions is triggered by the high consumption of staple foods that are processed using fossil fuels [12]. But CO_2 is not the only one green house gasses. N_2O gas ranks second after CO_2 as a greenhouse gas with the highest volume of emissions. The gas turns out to come from solid waste that not many people know about, namely from nitrogen fertilizers, manure, and nitrogen-fixing legumes [13]. Reactive Nitrogen contained in fertilizers, both organic and non-organic, is usually released into the air in the form of N_2O while absorption by soil is very small. SO_2 produced from burning fossil fuels released into the air can trigger acid rain because it reacts with water to produce an acidic H_2SO_3 solution. [14]. The activity of using fossil fuels must be minimized immediately to save the future of the earth.Providing education-related to alternative energy to students is a wise choice that has a positive impact on environmental sustainability [4, 12]. Environmental education is needed to stimulate environmental awareness about the risks of climate change caused by environmental pollution which can be seen from changing student behavior [15]. This needs to be implemented immediately to change students' understanding of the risks of environmental damage from the short term to the long term. Students must be involved in observations so that they are able to analyze, answer, understand the relationship between methane gas and carbon dioxide in heating [4]. In the field of education, various efforts have been carried out to build students' fundamental concepts about environmental pollution, including through animated shows related to greenhouse gases [16], argument-based learning to answer and correct misinformation related to climate change [17, 18], through climate negotiation games [7], as well as through experiments in laboratories that observe greenhouse gas behavior on earth system models model [11, 19, 20]. The key to the success of all these strategies is that the teacher must have essential questions that are able to guide students to explore and find fundamental concepts related to environmental pollution. Questions equipped with reasons are expected to be able to minimize the occurrence of misconceptions [12, 21]. Besides, questions must guide students to produce products by optimizing natural materials that produce alternative energy [9]. In the RADEC learning model designed by Sopandi, these questions are known as pre-learning questions [22]. Pre-learning questions are different from assessment questions. They do not measure students' learning outcomes. They give hint to students about essential concepts that should be mastered by them. Students' responses and answers to them can help teacher identify students' needs both individually and classically. This pre-learning

questions are expected to be able to help students to be focus on fundamental concepts of chemistry, in this case related to environmental pollution. However, researches related to the validation of learning questions on the concept of environmental pollution have not been done. Therefore, the purpose of this study is to create valid pre-learning questions related to the fundamental chemical concept of environmental pollution.

2. Environmental Pollution vs Environmental Awareness

Concept mastery of environmental pollution and environmental awareness are two things to be achieved in learning through the implementation of the national curriculum and SDGs. Meanwhile, creative thinking indicators are needed to stimulate students to be able to create creative ideas that can minimize environmental pollution. Earth is the only habitat for humans to live, therefore it must always be preserved. Lessons related to science or the environment must contain these three values.

The quality of habitable water bodies at least meets physicochemical parameters, such as pH, temperature, dissolved oxygen, salinity, conductivity, as well as microbiological and atomic adsorption. Microbiological parameters (such as the number of *Escherichia coli*) are used to measure seawater quality because these microbes are very sensitive to heavy metal concentrations [23]. To restore water bodies with low levels of trace organic pollution, it usually through biological processes. This is because biological processes are economical and have high efficiency in wastewater purification [24]. One of the tools used to treat synthetic domestic waste that operates at high hydraulic and organic loading levels is RBC (rotating biological contractor). Figure 1 shows a schematic diagram of how the device works to purify water.

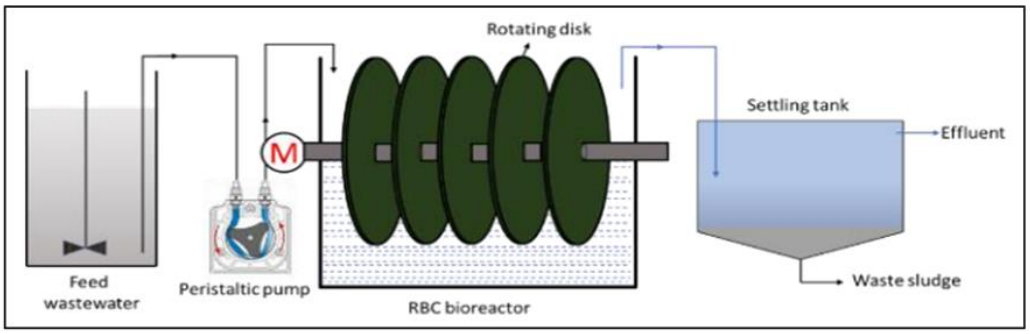

Figure 1. Conventional RBC unit [24]

Water bodies are usually mineralized and contaminated due to anthropogenic effects such as organic substances, nitrates, and even heavy metals [25]. The mineralized and contaminated water bodies are usually mining areas [26], [27]. Some of the heavy metals that are indicators of pollution are Zn, Cu, Pb, and Cd. These heavy metals will last a long time in the environment and accumulate in the food chain which will certainly harm humans and animals who act as consumers. Economical technique that is being developed to purify wastewater is infiltration-percolation technique with physical and chemical parameters. This technique was developed mainly to treat domestic wastewater that is contaminated and mineralized by heavy metals [28]. Greenhouse gases that are released into the air are also a major factor in reducing the quality of the environment. The fact that the consumption of fossil fuels is a quality of a country's progress is undeniable. This indicates that the main purpose of studying the fundamental concepts of

chemistry from environmental pollution problems is for students to have creative ideas to save the earth as a form of environmental awareness. Humans who have environmental awareness are now competing to find sustainable alternative energy.

Alternative energy that is processed from wood has the potential as an alternative source of biomass whose existence can be continuously renewed [29]. Even the opportunity to create oil from plastic waste is no longer a fantasy because the pyrolysis process has been discovered [30]. Some of the waste that can be processed into renewable energy is cooking oil derived from palm oil. The abundant cooking oil waste from various hotels and restaurants can be processed into biodiesel through the transesterification process [31, 32]. Figure 2 shows the chemical reaction of triglyceride or vegetable oil with ethanol assisted by a catalyst to produce biodiesel.

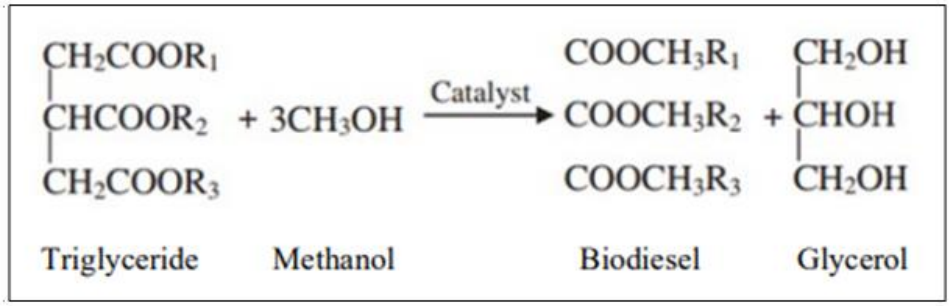

Figure 2. The stoichiometry process of biodiesel making

The emulsion of used cooking oil and water can also be processed into natural biodiesel [33]. Household waste such as vegetable waste can also be treated with a starter of sampi and EM4 to produce biogas. The biogas formed is methane in very large quantities [34]. Various agricultural wastes can also be used as alternative raw materials to create other alternative energy, including silica or chemical polymerization reaction of epoxy resin [35, 36]. Although the use of this energy still leaves a carbon footprint, it is hoped that the measurement of air pollutants will decrease gradually. Carbon monoxide, sulfur dioxide, nitrogen dioxide, volatile organic compounds, and particulates are greenhouse gases that must be reduced in industrial areas [37]. Scientists from Taiwan have even found a tool to predict weather changes in the next ten years in industrial areas with the metaheuristics-genetic algorithm [38].

The understanding related to the fundamental concept of chemistry is expected to be able to foster environmental awareness. Students are expected to have the skills to solve problems, be adaptive and have self-reflection, think critically, and be able to link theory and practice. They also understand how to reduce greenhouse gas emissions and carry out more complex analyzes of the link between rising sea levels, agricultural capacities, soil and water quality, flood risk, coastal habitat loss, and tourism, etc. They are also expected to have the skills to monitor the environment and analyze the results of the action and conduct an analysis of all the results and actions [39].

3. Methods

The study applied the type of design and development method. It aimed to produce pre-learning questions on the fundamental concepts of chemistry on the topic of environmental pollution. The development steps were; (1) identification and analysis of fundamental chemistry concepts in the national curriculum, SDGs, and indicators of

creative thinking skills, (2) development of prototypes of pre-learning questions, (3) expert validation test. At the end of the study, pre-learning questions were obtained on the topic of environmental pollution based on the fundamental concept of chemistry.

The questions on the fundamental concepts of chemistry on the topic of environmental pollution were prepared based on the national curriculum in science subjects, the SDGs (sustainable development goals) curriculum for lower secondary school level [39], and creative thinking indicators [40]. The questions contain chemical representation such as macroscopic, sub-microscopic, and symbolic. They also involved the contents on greenhouse gases, water pollutant, pesticides, nano-plastics, and alternative energies. Those contents were adjusted based on the level of lower secondary school students' development thinking. The questions that have been made were then validated by two chemistry education experts and an expert in biology education. Furthermore, the data from the validation results were carried out by the Kendall Test to determine the validity of the instrument's assessment by the validator on three aspects, namely compatibility pre-learning questions with national curriculum indicators and SDGs, compatibility pre-learning questions with the indicators of creative thinking skills, and the clarity of language use. All statistical tests were carried out by SPSS ver.26. If the value of Asymp.Sig. > 0.05 then all pre-learning question items have appropriate content validity.

4. Results and Discussions

4.1. Analysis of fundamental chemistry concepts on curriculum

Fundamental chemistry concepts on environmental pollution material were obtained by analyzing the basic competencies of grade 7 secondary school on the theme of environmental pollution and global warming and the SDGs secondary school curriculum in goal 6 on clean water and sanitation and goal 13 on climate action. Besides, an analysis was also carried out on indicators of creative thinking skills. There are ten indicators resulting from the analysis of the three documents. The following is a more detailed explanation in Table 1. If we analyze all the indicators and fundamental concepts of chemistry that will be used for the pre-learning questions above, almost all of them have become socio-scientific problems. Pre-learning questions with socio-scientific issues are usually able to present students' arguments so that long-term memory is obtained [7, 17]. These pre-learning questions will be equipped with reasons so that they are not only give hint to students on essential concept but also can diagnose students' misconceptions classically [1, 12].

The pre-learning questions on the indicator 1 guide students to understand pollutant migration by connecting the concept of convection and understanding of particle concept. When students understand the concept of particles and change states of matter, they will understand how pollutants dissolve in water bodies and experience convection so that pollutants spread far in water bodies [45]. Pre-learning questions on indicators 2 and 3 also explored students' understanding of heavy metals that pollute the environment. Controlling the concentration of heavy metals is very important because of sustainability environment [23, 27, 28]. Students are expected to be able to analyze the presence of these heavy metals in the environment because various types of metals have been previously introduced through elements and compounds

Table 1. Fundamental chemistry concepts on environmental pollution

No.	Indicator(s)	Fundamental Concept of Chemistry
1	Explaining how solid, liquid, and gaseous pollutants migrate	a. Solid wastes such as plastic and liquid waste migrate in the ocean due to ocean currents. Ocean currents are caused by convection where convection occurs due to differences in water temperature, so water with a higher temperature (lower density) moves from the surface of the water to the seabed. This movement is also followed by lower temperature (higher density) water moving up from the seabed to the surface. [41]. b. Polluted air will expand when it gets a high intensity of sunlight and becomes lighter. The surrounding air pressure drops as the density of the air decreases. This gaseous pollutant will flow to a lower pressure area.
2	Analyzing the impact of organic and non-organic fertilizers on the composition of the air	Organic and non-organic fertilizers have reactive Nitrogen which is released into the air to become N_2O. The addition of N_2O gas increases the concentration of greenhouse gases in the earth's atmosphere.
3	Analyzing the impact of pesticides on water bodies	Seven out of ten pesticides on the market contain heavy metals such as Pb (lead) [42]. Lead from pesticides will flow and accumulate in water bodies as waste. Pb that enters through the respiratory tract and digestive tract can enter the blood and binds to erythrocytes and is metabolized by the body into the proximal tubule so that this can interfere with kidney function itself, besides that Pb that enters the blood will inhibit heme synthesis so that will reduce the production of blood Hb which can result in the emergence of other health problems [43].
4	Analyzing the process of acid rain	Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_X) are emitted into the atmosphere and moved by wind and air current. When SO_2 and NO_X react with water, oxygen, or other chemicals, they form H_2SO_4 and HNO_3 then fall to the ground.
5	Analyzing the impact of oil spills on aquatic life	The oil layer blocks the exchange of O_2 from the atmosphere into the ocean and reduces the solubility of O_2 in water bodies so that the amount of O_2 is not sufficient to support aerobic marine life.
6	Analyzing the impact of deforestation on air quality	Chloroplasts in green plants play an important role in photosynthesis. If the number of green plants decreases, it is certain that the amount of CO_2 will continue to increase while the amount of O_2 in the atmosphere will continue to decrease.
7	Creating ideas related to waste management in river bodies so that water can be reused for sanitation	a. Utilizing alum with the chemical formula $Al_2(SO_4)_3.18\ H_2O$ so that the coagulation process occurs in water bodies. Here's the chemical reaction. $Al_2(SO_4)_3.18\ H_2O + 3\ Ca(OH)_2 \rightarrow 2\ Al(OH)_3 + 3\ Ca(SO_4) + 3\ CO_2 + 18\ H_2O$ b. Filtering plastic waste with simple tools so that plastics are not eaten by marine biota and enter the body of marine biota as nano-plastics.
8	Creating ideas on how to filter soot in factory chimneys	In addition to filtering dust with a simple filter, a filter membrane containing liquid NaOH can also be used [44].
9	Analyzing the impact of increasing greenhouse gases on global warming	Greenhouse gases such as CH_4 or CO_2 form a thick layer in the earth's atmosphere which functions to absorb the heat energy of the sun's rays to keep the earth's surface temperature warm. The addition of the volume of greenhouse gases will increase the ability to absorb heat in the earth's atmosphere so that the earth's surface temperature increases.
10	Creating ideas for reducing greenhouse gas emissions through cookware with alternative fuels	The principle of cookware with solar alternative energy fuels works on the principle of the greenhouse effect. Besides, the fuels can be produced from cooking oil through transesterification process.

. The pre-learning questions on the indicator 7 discussed about plastics that accumulate in water bodies and even become nano-plastics in marine biota through the food-chain process. The follow-up pre-learning questions can focus students that the problem of plastic waste can be overcome by converting plastic waste into new energy sources [30]. Even other wastes that may accumulate in water bodies can be processed into new alternative chemical energy sources. Besides, the pre-learning questions on indicators 8 and 10 are needed not only to stimulate and build students' creativity but also to build environmental awareness as a form of effort to create energy sustainability [9]. The question number 9 is intended for them to understand the relationship between greenhouse gases, especially carbon dioxide and methane, to global warming in various countries. This question educates students that the greenhouse effect has a global impact, not only in developed countries with high consumption of fossil fuels [18, 19]. Besides, in conveying the questions, the teacher also needs to provide follow-up questions related to greenhouse gas behavior so that students understand global warming. The teacher does not have to simulate how CO_2 gas has differences in heat retention in the presence and absence of a CO_2-enriched atmosphere within an open beaker containing gravel that serves as a model Earth system [20]. Besides, alternative energy sources that can be collected from students are not only in the form of solar energy. The 3R (reduce, reuse, and recycle) movement is expected to inspire students to process waste into new energy sources, one of which is cooking oil. Cooking oil is a household waste that produces a relatively high carbon footprint, therefore the waste must be optimized so that it becomes a new energy source into biodiesel [31, 33]. Vegetable waste from households can also be processed into a new energy source, namely methane. It is surprising that the amount of methane produced from this source is large because the source is abundant [34]. In the science curriculum at the lower secondary school level, various concepts have been studied so that the task of pre-learning questions is to connect and explore science concepts that must be understood by students.

4.2. Expert content validation result

The content validation was carried out by three experts from chemistry and biology education by using SPSS ver.26 through the Kendall test. The results of the content validity test are presented in Table 2.

Table 2. The summary of statistical test with spss ver.26

	Criteria		
	Compatibility Pre-learning Questions with National Curriculum Indicators and SDGs	**Compatibility Pre-learning Questions with Creative Thinking Indicators**	**Clarity of Language Use**
Asymp.Sig	0.861	0.779	0.917

Based on Table 2 the Asymp.Sig value is above 0.05. This means that H_0 is accepted or ten items of pre-learning questions have content validity in accordance with the three criteria above. Based on the data from Table 2, pre-learning questions can be used to guide students to be focus in learning fundamental concepts of chemistry in the framework of the national curriculum and SDGs in an easy-to-understand language. Besides, these pre-learning questions can develop students' creative thinking skills with easy-to-understand language as well. Language in pre-learning questions has a very dominant role so that learning objectives can be achieved. The valid result is also because the process of preparing pre-learning questions is preceded by curriculum analysis and its creation involves

experienced teachers. The Asymp.Sig. value of compatibility pre-learning questions with national and SDGs curriculum was above 0.05 because both curriculums have the same framework on knowledges and understanding aspect, skills and applications aspect, and values and attitudes aspect. In the national curriculum, they are known respectively cognitive, psychomotor, and affective aspects [39]. Due to the similarity factor, the indicators in the national curriculum and the SDGs curriculum synergize with each other in the construction of questions. Meanwhile, the Asymp.Sig value of compatibility pre-learning question with creative thinking indicator was above 0.05 because creative thinking is actually one of the special developments of skills and applications aspect that must be possessed by students in achieving SDGs in 2030 [39, 46]. The language aspect is also one of the things that must be considered because the inability of students to answer questions is not necessarily because students do not understand the concept but also because students do not understand the language in questions that are too complicated or too high. The pre-learning questions are structured to help students focus on learning the material that must be mastered based on the student's career development needs and the curriculum used.

5. Conclusion

The results showed that the pre-learning questions containing the fundamental concept of chemical concepts for environmental pollution were valid for aspects of the suitability of pre-learning questions with indicators of the national curriculum and SDGs, compatibility of pre-learning questions with indicators of creative thinking, and clarity of language use. All Asymp.Sig values are above 0.05, which are 0.861, 0.779, and 0.917, respectively. The pre-learning questions are divided into ten indicators containing the mechanism of pollutant migration, the impact of pollutants on the environment, and ideas for solving environmental problems.

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