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GLOBAL WARMING: PROMOTING ENVIRONMENTAL AWARENESS OF SENIOR SECONDARY SCHOOL STUDENTS FACING ISSUES IN THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

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Abstract

This research aims to design effective global warming learning to build environmental awareness for young people, especially facing issues in the Sustainable Development Goals (SDGs). Learning effectiveness is measured through the collaborative skills profile. Learning was designed by considering several aspects, including previous learning, a literature study of global warming, government policies, as well as sharing and jumping tasks. The developed lesson design was tried out in grade ten of a senior high school in Bandung, Indonesia. The learning process, both audio and video, during the trial was recorded for further analysis. Audio/video were transcribed for analysis applying collaborative skills indicator. It was found that global warming learning was quite effective as indicated by the growth of 7 indicators of collaborative skills in students. Students can build dialogue, respect each other, work together, and care for each other. This research produced the lesson design of global warming that is empirically validated to inspire teachers.

Keywords: Collaborative skills, Environmental awareness, Global warming, Sharing and jumping tasks.

1. Introduction

Global warming, a phenomenon of grave concern, is a direct consequence of human activities. This becomes main concerns since the world opens issues in the Sustainable Development Goals (SDGs). This global warming phenomenon has reached attention for researchers in many aspects, especially relates to climate change [1-7]. The primary culprits are the burning of fossil fuels (petroleum, coal, etc.) and the ongoing deforestation, which is traced back to the Industrial Revolution [8]. These activities significantly contribute to the increase in greenhouse gas concentrations, particularly CO_2, which is the main driver of global warming and climate change [9].

According to Indonesian statistics, one of the causes of carbon dioxide emissions is the burning of motor vehicle fuel. Therefore, many studies on fuel, including fuel alternatives and ignition improvements, have been well reported [10-13]. In the past ten years, the development of motorcycles in Indonesia has grown significantly; In 2012 there were 76,381,183 motorcycles and in 2022 there were 125,767,349 motorcycles. Approximately one million more automobiles that run on fossil fuels are added every year; in 2012, there were 10,432,259 cars, and the study shows that there are 17,175,6220 cars. According to the recently released study "Climate Change in the Mind of Indonesia," conducted by the Yale Program on Climate Change Communication (YPCCC) in partnership with Development Dialogue Asia, Communication for Change, and Kantar Indonesia, 76% of Indonesians surveyed said they know "somewhat" (55%) about global warming, while 20% have never heard of it. A lot of people are aware, the weather in their area varies. But in order to comprehend why these changes are occurring, they lack an understanding of climate change.

Indonesia reported to the UN in 2022 with plans to surpass the targets of the Paris agreement by reducing emissions by roughly 43% with international assistance and by further prioritizing the development of sustainable energy sources. Environmental awareness is fostered in high school chemistry classes by discussing themes such as climate change and global warming. The Ministry of Education, Culture, and Technology has supported reducing carbon emissions by emphasizing the school curriculum. This policy supports Education for Sustainable Development (ESD) [14]. ESD is the hottest subjects recently, increasing attention of researchers in many aspects [15-18].

To reach the goal, a teaching learning sequence could be useful as a reference for creating a lesson design. It includes all important concepts about global warming, their learning sequence, and the relationship between all of the concepts. These concept maps and sequences are the results of the re-personalization and re-contextualization process, which is important as a basis for developing sharing and jumping task designs.

We interested in researching how to teach global warming effectively to senior high students. The concept map and sequence of global warming topics is used for development of lesson design. Sharing tasks and jumping tasks is applied to promote collaborative learning. Through this research, students are also expected to be able to have more empathy towards the environment and find out the solutions to this environmental problem using the three pillars of ESD. The novelties of this study are (i) promoting environmental awareness, (ii) ESD-oriented, (iii) sharing and jumping task based lesson design, and (iv) collaborative based learning.

2. Global Warming and Its Learning

2.1. Global warming

About half of the sun's radiation energy reach the Earth. However, radiation also absorbs, reflects, and even leaves the atmosphere. Particulates, clouds, or gases cause this in the atmosphere. When the radiation is absorbed, the energy does not damage the covalent bonds but change the direction of rotational movement or vibration of the molecules. Infrared light cannot be absorbed by monoatomic molecules. The molecule must undergo a corresponding change in dipole moment due to the absorption of radiation. This cycle led to global warming human activities have accumulated over several decades accelerate it [19]. Figure 1 explains mechanism of the natural and human enhanced greenhouse effect.

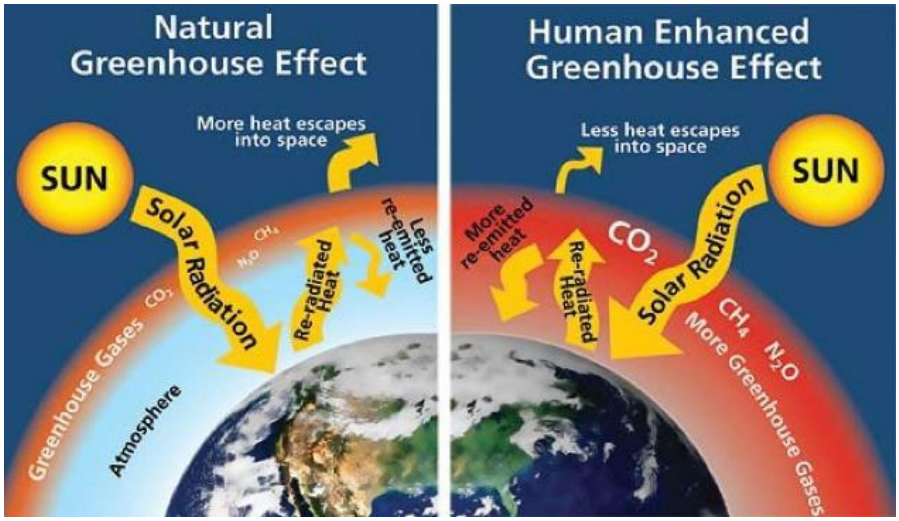

Fig. 1. Greenhouse effect mechanism that causes global warming (adopted from https://carbonconnections.bscs.org/unit-1/1.3-carbon-forcing/) Retrieved on June 2024.

The rise in sea level is one of the most important consequences of climate change. It has attracted worldwide attention, especially in low-lying areas and also on small islands, where there is a risk of their area decrease due to erosion. The situations mentioned result in the people in the area having to relocate to different areas [20].

Transport and infrastructure in nations like Canada, particularly in the north, are built to withstand various kinds of ice and snow. If climate change materializes, the area will face economic challenges [21].

The environment impacts body temperature, and it adjusts accordingly. The human population is seriously threatened by the rise in global temperature brought on by global warming. More people die in America from extreme heat than from other weather-related disasters. Excessive heat can cause heat stroke and dehydration and exacerbate pre-existing medical conditions like respiratory and cardiovascular disorders [22]. Figure 2 shows the global warming impact.

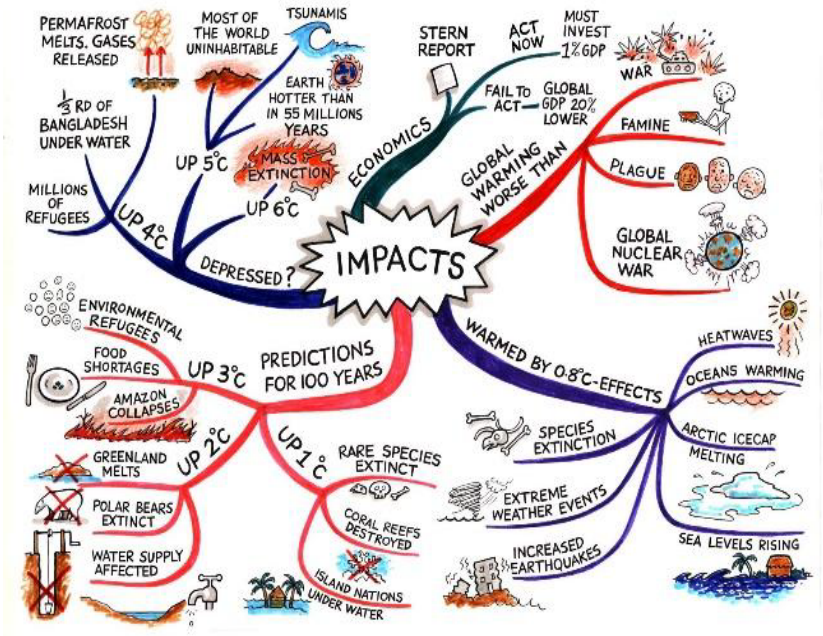

Fig. 2. Global warming impact (adopted from https://fvcgeography.wordpress.com/the-restless-atmosphere/greenhouse-effect-global-warming/) Retrieved on June 2024.

Global warming has a serious impact on human survival. The campaign on the issue of global warming must be of concern to all parties, especially in education at all levels. The issue of global warming for students to address includes understanding the phenomenon through investigation and applying it in everyday life.

2.2. The 21st century skills

Students need to have 21st century skills [23, 24]. It includes creativity, communication, collaboration and critical thinking skills [25]. One of the abilities required of students to fulfil Pancasila's high ideals is collaboration. Collaborative skills are the capacity to engage in any activity that fosters relationships with others, respects those relationships, and functions as a team to accomplish a shared objective [26]. These skills are related to a social constructionist theory called the Zone of Proximal Development (ZPD). This theory explains the help of other more capable people, students do and understand more things. This theory was presented by Vygotsky, who found the cognitive development of students is influenced not only by teachers, but also by communication with peers [27]. If cooperative skills are sufficient, classroom learning is no longer teacher-centred because students interact a lot with other students, while the teacher becomes only a facilitator [28].

For collaborative skills to emerge in students, learning designs are needed help students to improve understanding, critical thinking skills, interpersonal relationship skills, and good attitudes during learning [29]. To bring out collaborative skills in students, learning material should challenge students is very

important, so it encourages students to think, communicate, and collaborate. Massaki in Asari [30] explains when students face a challenging problem, students exchange opinions with each other collaboratively, this indicates the problem given by the teacher is responded to by students critically and they will try very hard to solve the problem. Indicators of collaborative skills are needed to find out how much students produce activities are included in collaborative skills. The following are collaborative skills indicators: (i) asking friends/teachers when they do not understand, (ii) being able to speak or argue, (iii) appreciating and respecting the opinions of others, (iv) working together to solve the problems, (v) show concern for friends, (vi) being able to guide others to achieve goals, and (vii) uses problem-solving skills for goal completion.

Collaborative learning should not only be about facts but also they already know (sharing task), but also require challenges (jumping task). Before taking the Jumping task, students must prepare the foundation of necessary knowledge. More broadly, a sharing task is a learning activity using problems are predicted to be solved directly by students, while a jumping task is a learning activity using problems for students to solve with high-level thinking abilities [31]. High-level abilities are very important in learning chemistry.

2.3. Lesson design

Lesson design is the main reference in every problem formulation and implementation of learning for teachers. In this research, lesson design was developed which is a didactical design to help teachers analyse students' learning obstacles [32]. Didactical design is a design created by the teacher before teaching based on the analysis carried out.

In a lesson design, one of the things must be present is the rationalization of choosing a learning approach or strategy [33]. In selecting learning strategies, teachers must adapt to the values or competencies in the curriculum. Currently, in Indonesia, the Merrdeka curriculum and 2013 curriculum require student-centred learning and meet 21st-century competencies. One of the competencies emphasized in both curricula is students' collaborative abilities. This competency is stated in the Pancasila Student Profile in the Merdeka curriculum. The lesson design included the learning strategy of sharing and jumping tasks. This strategy trigger collaborative learning because some tasks or exercises stimulate students' thinking, communicating, and collaborating abilities.

Tasks or problems trigger student collaboration are important because they stimulate students' thinking, communicating, and collaborating abilities. To be able to create a collaborative atmosphere in learning, the teacher is a facilitator whose role is to guide students to solve the tasks or problems given. The teachers must be creative to adjust the tasks or problems, so students feel capable, challenged, and think hard in their group discussions. To make it easier for teachers to achieve this, Sato in Hobri et al. [34] divides tasks or problems into two types sharing and jumping tasks. Sharing tasks are tasks or problems for all level students' abilities or almost all students solve. Sharing tasks aims to sharpen students' analysis both individually and in groups [35] while jumping tasks are tasks or problems have a level far above students' abilities or not all students solve them, so they challenge students and trigger the emergence of students' collaborative skills.

2.4. Zone of proximal development

Collaborative skills are important for students need to have. In addition to curriculum demands, collaborative skills have an impact on student development. When students are guided by teachers or collaborate with more capable friends, students are in a state of exceeds their level of ability or knowledge when working independently. The distance between independent and collaborative student abilities is called the Zone of Proximal Development (ZPD) [36].

3. Method

The first stage was planning the research. The focus was designing the challenging lesson on global warming by reviewing the lesson plan of global warming that was previously implemented, interviewing chemistry teachers to get insight, conducting a literature review to re-personalize and re-contextualize, and observing student learning by chemistry teachers. Then we predicted student responses and their anticipation, prepared concept maps and sharing-jumping tasks, and prepared student worksheets which are packaged in a lesson design. The next stage was implementing the developed lesson design by a prospective teacher in grade ten. While other teachers collect the data by observing and recording the student's learning. The last stage was verification and improvement. A collaboration indicator was applied for the verification of student learning on global warming. The product of this research was edited/empirical lesson design for next lessons. The detail of research flow is shown in Fig. 3. This procedure was carried out in a Senior Secondary School in Bandung, Indonesia.

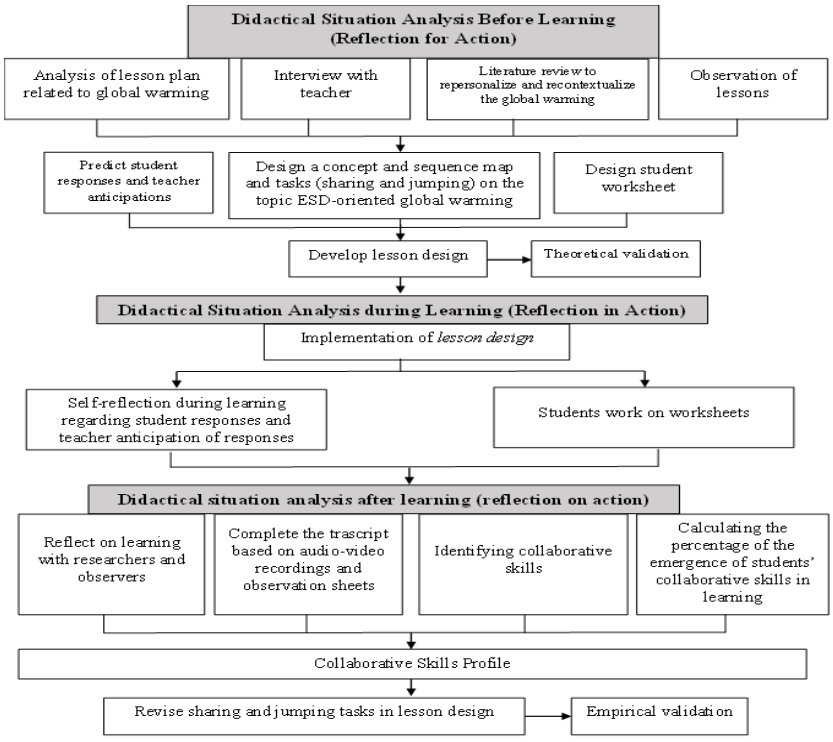

Fig. 3. Research flow.

4. Results and Discussion

4.1. Lesson preparation: Didactical situation analysis before learning (Reflection for action)

The lesson plan for global warming that implemented previously consists of 14 pages including (i) general information about global warming, (ii) core competency, and (iii) attachments. According to the lesson plan, discovery learning was applied as a learning model for 180 minutes of meetings in the first semester of 2023. The core competency section outlines the learning stages. However, these stages only explain what the teacher must do at a certain time, there is no anticipation of what the students will answer or do.

The previous learning was about the Basic Law of Chemistry to Stoichiometry. At the beginning of learning, students focused on the teacher who was explaining. However, after some time, some students seemed to lose interest in what the teacher was saying. Some students also played with their mobile phones or discussed things with friends had nothing to do with the learning materials. The anticipation of the teacher to restore students' focus or interest in their learning was asking questions. For some students, this could not work because there were students who were unwilling or unable to answer, thereby hindering learning. Delivery of lesson materials through lectures causes students to be less interested.

The online interview between the researcher and teacher was done to get information on the global warming lesson. Table 1 shows the questions and the answers between the researcher and the teacher.

Table 1. Online interview.

Researcher	Teacher
How do you usually teach about global warming?	Differentiated learning and teachers as facilitators
What learning strategies are usually used in the global warming learning process?	Learning method was discussed; Learning media: (i) printed media official chemistry book by the Indonesian Government, (ii) articles, (iii) worksheet; 180 minutes for two meetings in the first semester on second and third weeks of October 2022
What concepts do students learn in global warming materials?	(i) Understanding global warming, (ii) causes of global warming, (iii) how to measure global warming, (iv) climate change, (v) impact of global warming, control global warming, the impact of global warming in Indonesia
What was the role of students and the efforts made to ensure students remain active during the learning process on the topic of global warming?	Students were enthusiastic. Communication took place not only from student to teacher or vice versa, but also from student to student. Students already know during the discussion an activeness evaluation is carried out.
Were there any difficulties experienced by students in the process of learning the topic of global warming?	Limited internet network to find references. Meanwhile, the school's internet connection was slow.
How did you overcome the difficulties faced by students during the learning process?	Through discussion, groups could help each other so they could overcome these difficulties

Before designing the challenging lesson, we conducted a literature review to re-identify and contextualize the global warming content. By now, information had

been gathered from a variety of literary sources via search engines like Google Scholar, Springer, Elsevier, etc. For additional research, ten literature sources were consulted. The following sources are categorized by type: Literature is denoted by codes BK1 and BK2, and journal articles are denoted by codes R1-R8. Table 2 contains a list of literature sources.

Table 2. List of literature sources.

Title	Year	Author	Code
Environmental Chemistry 9th Edition	2010	Stanley E. Manahan	BK1
Principles of Environmental Chemistry 3rd Edition	2013	James E. Girard	BK2
Greenhouse Gases, Radiative Forcing, Global Warming Potential and Waste Management - an Introduction	2009	Charlotte Scheutz, et al..	R1
World Greenhouse Gas Emissions in 2005	2009	Tim Herzog	R2
Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming	2017	Darkwah Williams Kweku, et al..	R3
Sea-level rise caused by climate change and its implications for society	2013	Nobuo MIMURA	R4
Implications of Climate Change for Economic Development in Northern Canada: Energy, Resource, and Transportation Sectors	2009	Terry D. Prowse, et al..	R5
Social and economic impacts of climate change on the urban environment	2011	Rebecca Gasper, et al..	R6
Reduction of CO_2 to Chemicals and Fuels: A Solution to Global Warming and Energy Crisis	2018	Sebastian C. Peter	R7
Global warming threatens human thermoregulation and survival	2020	Rexford S. Ahima	R8

Table 3 shows the results of the review of ten literature sources. Seven discussions on global warming learning are included in the table.

Table 3. Summary of the results of the literature review.

Content	Analysis results
Natural Occurrence of Greenhouse Gasses in The Atmosphere	Sulfur, nitrogen, and carbon dioxide gases are essential atmospheric substances. Compared to any other gases, CO_2 is the most abundant. CO_2 is necessary for plant photosynthesis [BK2]. CO_2 also plays a vital role in keeping the Earth warm. Naturally, the atmosphere can be analogous to a blanket to warm and shield the planet from outside dangers including ultraviolet radiation [BK2]. Gases such as CO_2 and water vapor play a role in warming the troposphere because these two gases can absorb the results of reradiation in the form of infrared and reradiate [BK1]. However, if the concentration of this gas continues to increase at its current level, adding two ppm per year, global warming will quickly occur and damage the climate [BK1].
Greenhouse Gases Are Produced by Human Activity	Gases that contribute to the greenhouse effect in the atmosphere are known as greenhouse gases. While gases like CO_2, CH_4, N_2O, and halogenated hydrocarbons could be found in nature. On the other hand, anthropogenic greenhouse gases are greenhouse gases produced by people [BK2]. Activities such as deforestation or using fossil fuel-powered vehicles emit these gases.
Electromagnetic Radiation and	Convection and conduction carry less than 1% of the sun's energy to Earth. The remaining 99% are caused by radiation. This solar energy manifests as electromagnetic radiation, which is separated by wavelength and can take several

Content	Analysis results
Greenhouse Gas Absorption of It	forms, such as heat, UV light, radio waves, and visible light [BK1 and BK2]. Earth receives around half of the solar radiation. While some of them reach the Earth's surface directly, others are dispersed or reflected [R1] by gasses, clouds, or other elements in the atmosphere. A portion of this energy is instantly absorbed or reflected by the atmosphere, and after some time, it is released again as infrared [BK1 and BK2]. Once the electromagnetic radiation transforms into infrared radiation, it does not immediately leave the atmosphere. This is because it is reabsorbed by certain gases, which we refer to as greenhouse gases [R1]. When these gases absorb the radiation, the energy does not damage their covalent bonds. Instead, it alters the direction of their rotational movement or vibration. It is important, monoatomic molecules are unable to absorb infrared radiation. A molecule must experience a matching change in dipole moment as a result of vibration or rotation in order to absorb it [R1]. Diatomic or polyatomic molecules, on the other hand, have dipole moments and vibrate or rotate when they absorb infrared light [BK2].
The Greenhouse Effect	The greenhouse effect is why the atmosphere is a blanket covering the earth. In the atmosphere, especially in the stratosphere, greenhouse gases absorb infrared radiation. After the infrared radiation is absorbed, it is reradiated, then re-absorbed by greenhouse gases, and create a chain reaction. This is the reason why the stratosphere has an average temperature of 18°C. The average temperature of the world would most likely drop to -15°C if this mechanism had not happened [BK1, BK2 and R2]. But when greenhouse gases -especially CO_2 - increase, the planet will suffer global warming, which has already happened. [BK1].
Global Warming Potential	The term "radiative forcing" (RF) is frequently used to describe the extent of variations in the average radiation in the tropopause, the outermost region of the troposphere [R1]. However, its use of greenhouse gases is easier to understand. The forcing caused by increasing greenhouse gas concentration depends on the characteristics of each gas, the amount of its concentration in the atmosphere, the temperature profile and thickness of the atmosphere, the lifetime in the atmosphere, and its relationship with available clouds [R1]. GWP is a measure of how much each greenhouse gas contributes to global warming, representing the RF value in a period (for example, 100 years) in mass units (1 kg), which is relative to CO_2 [R1]
Global Warming Impacts	Environment: The consequences of rising sea levels, a critical impact of climate change, are far-reaching. Particularly in areas with low altitudes and small islands, the risk of land erosion is high, leading to the potential shrinkage of these areas. In turn, this forces the population to migrate to other regions or countries, underlining the seriousness of the problem [R4]. Economy: Infrastructure and transportation systems in nations like Canada, particularly in their northern areas, are built with special features to handle various kinds of snow and ice. Should climate change materialize, it will provide an economic challenge for the area [R5]. Socio-cultural: The environment influences body temperature and changes appropriately. A significant hazard to humanity is the rise in global temperature brought on by global warming. More people die in America from severe heat than from any other weather-related calamity. [R8].
Solution	The increase in greenhouse gases, particularly CO_2, is the main driver of global warming. This change in radiative forcing value is causing geothermal heat to rise to its normal limit [R1]. It is important, CO_2 gas is the root cause of this problem [BK1, BK2, and R1]. However, there is hope. The best way to address this global issue is to cut back on human-caused CO_2 emissions and work toward a net zero level. This is a measurable and doable objective [R7].

Based on the results of the literature review in Table 3, we structured it to see the patterns of relationships and interactions and then expressed it in the form of a concept and sequence map in Fig. 4.

On the concept and sequence map, we made 9 small circles connected by lines to understand the topic of global warming. From one small circle to another we designed questions. The first question to connect circles 1 and 2: "Is there a connection between global warming and natural or human activity?". We predicted the student response: "Global warming occurs due to activities both from nature and humans". The questions and predicted student responses are summarized in Table 4. Questions and predictions of student responses on the consequence map are materials that will be considered in developing lesson design.

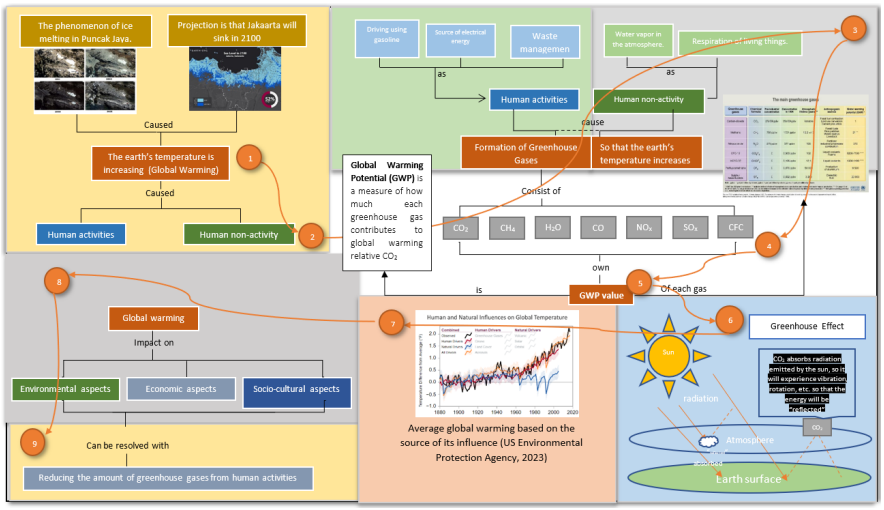

Fig. 4. Concept and sequence map.

Table 4. Questions and predictions of student responses on the consequence map.

Relationship between circles	Questions (teacher anticipation)	Student response prediction
1 and 2	Is there a connection between global warming and natural or human activity?	Global warming occurs due to activities both from nature and humans.
2 and 3	Which natural and human-caused processes lead to global warming?	Human activities: driving using gasoline, fossil energy sources, waste management. Natural activities: water vapor in the air, respiration of living things.
3 and 4	What chemical products result from these activities?	CO_2, CH_4, H_2O, CO, NO_X, SO_X, and CFC.
4 and 5	To what extent does each of these substances contribute to global warming?	A measurement of the impact of greenhouse gases on global warming is called the global warming potential.

Relationship between circles	Questions (teacher anticipation)	Student response prediction
5 and 6	What is the process of chemicals resulting from human activities in global warming?	The earth reflects solar energy back to space, where it is absorbed by CO_2 in the atmosphere. This causes the CO_2 molecule to vibrate or rotate, which raises the earth's temperature.
6 and 5	Considering these chemical reactions, which molecule is most responsible for global warming?	CO_2 because it causes a greenhouse effect.
5 and 7	From where these substances originate?	Human activities, for example, the use of fossil fuels for motorized vehicles.
6 and 8	What aspects are affected by global warming?	The environment, economy, and social culture—the three pillars of ESD—are all impacted by global warming.
8 and 9	What is the solution to global warming?	Since greenhouse gas emissions are a direct result of human activity, we must restrict these activities.

4.2. Lesson Design

Lesson design is an adjustable guideline for teachers to improve student learning during the learning process. Lesson design allows teachers to adapt for learning improvement based on reflection during the learning process according to the class situation. To develop a lesson design, teachers must imagine what will happen to our class. In this case, we developed questions and student responses regarding global warming based on the above consequence map which is arranged on a sheet of paper to trigger student learning. These questions are intended as sharing tasks to cover content from the textbook and jumping tasks are more challenging problems beyond the textbook. We hope all students solve the problems through sharing among them. The developed lesson design for global warming topic is shown in Fig. 5.

The lesson design in Fig. 5 consists of 8 columns, each column has a question at the top and an arrow connecting the student's response prediction at the bottom. The first column contains jumping tasks, "Why is the ice at Puncak Jaya melting and Jakarta is predicted to sink in 2100? Columns 2 to column 7 contain sharing tasks as teacher assistance in the form of scaffolding. The last column contains the second jumping task, "How does human activity influence global warming?", so students continue to think. The curve line connecting the bottom left corner and the top right corner depicts the student's learning trajectory.

The lesson design was tried out at grade ten 10 of a senior secondary school in Bandung city. Thirty-six students were grouped into 6 groups of six students randomly. The teacher distributed worksheets containing questions to guide students in group work in 90 minutes. The learning process was recorded via audio/video recorder, then the recording was transcribed for further analysis based on collaboration skills indicators.

The collaborative skills profile is shown in Fig. 6. Figure 6 shows all indicators of collaborative skills developed in research targets, senior high school students on the topic of global warming.

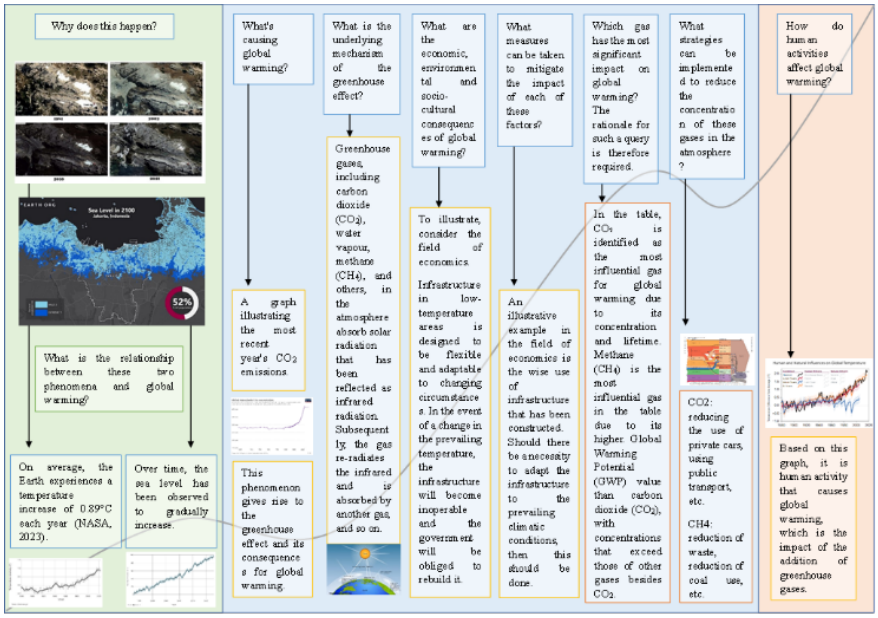

Fig. 5. Lesson design of global warming.

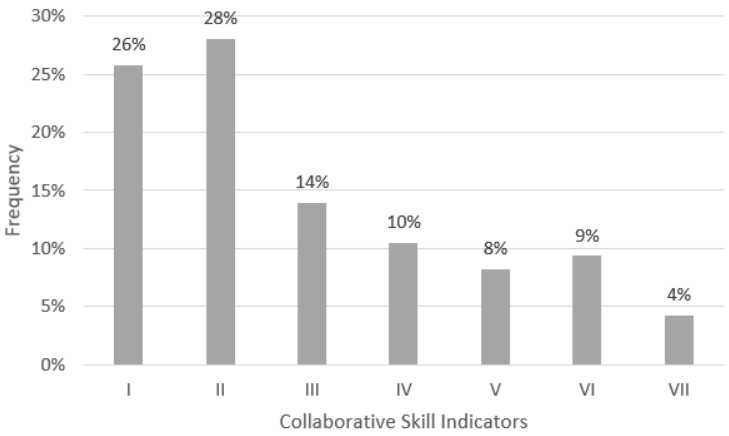

Fig. 6. Student's collaborative skill profile.

Based on Fig. 6, the second indicator of collaborative skill, "Being able to speak or argue", is the most developed while the seventh indicator of collaborative skill, is the least developed. This is because students were given many challenging problems to discuss in the groups. However, students are not used to solve problems as seen in indicator number seven in Fig. 6 which is the lowest.

Collaboration skills indicators: (i) asking friends/teacher when they do not understand, (ii) being able to speak or argue, (iii) appreciating and respecting the opinions of others, (iv) working together to solve problems, (v) show concern for friends, (vi) being able to guide others to achieve goals, and (vii) uses problem-solving skills for goal completion.

The most common collaboration indicator after (ii) is indicator (i), "asking friends or teacher when they do not understand". Indeed, indicators (i) and (ii) are very related so this causes dialogue among students. Figure 7 shows an example of students asking their friends to understand.

Student	Conversation
S4	"So, it affects humans, right?"
S2	"No, because human activities regarding global warming."
S3	"Human activity has a big influence on global warming because…Because humans produce CO2"
S2	"So, it is because of global warming."
S3	Yes, so, both events were caused by global warming, Well, the main problem is the temperature is increasing. So, it melts the ice. Because of this, volume of the water on earth increases and the land becomes more narrow."

Fig. 7. Example conversations of students ask their friends.

Figure 8 is an example of student conversation falls into the collaborative indicator (iii), namely respect. We can see the students respect each other opinion.

Student	Conversation
S1	"So what are the words should we write?"
S2	"'From global warimng and greenhouse effect'?"
S3	"Can this be the answer?"
S4	"No, 'because it (greenhouse gas) abosrbs too much'"
S2	"Awesome, right? Continue to be absorbed back into the earth?"
S1	"If we have a greenhouse effect, the erarth absorbs it (radiation) less effectively, you know?"
S2	"Oh, I see."

Fig. 8. Example conversations of students respect each other opinion.

An example of a conversation indicates the emergence of the collaborative indicator (iv), namely, working together. Figure 9 shows an example of students working together to find a solution.

Student	Conversation
S3	"Well, why is there less and less? If we look at the graph, we see if the earth's temperature increases, the snow automatically melts. First like this, first sunlight is emitted.."
S2	"This first? It says 'First…'?"
S3	"It is okay"
S2	"At first…"
S3	"Well, so initially the sun's ray was emitted to the earth. So these poles reflect some of the light comes to earth."

Fig. 9. Example conversations of students that are working together.

The fifth collaborative indicator shows concern for friends who are in trouble. This is characterized by students showing empathy towards their friends or encouraging their friends to play an active role in learning. The following is an example of a conversation according to indicator number five.

S3: "Let's answer it"

……

S3: "Who wants to look into the economic aspects?"

The sixth collaborative indicator is being able to guide other people to achieve common goals. The emergence of this indicator during learning occurred only 10% of the total. Of the five groups, only group three and group five seemed consistent in generating this indicator. The other three groups showed indicators of being able to guide other people only at the beginning of learning. This is understandable because some students need help from others from the beginning.

This study adds new information in science education, especially in chemistry education as reported elsewhere [37-42], bringing new ideas for improving teaching and learning process.

5. Conclusion

Based on the results of the discussion, the following conclusions are as follows:

- The results of learning documents, interviews with teachers, learning observations as well as the re-personalization and re-contextualization process carried out through the study stages of material about global warming from various literature resources are very useful in creating learning designs.
- Lesson design on the topic of ESD-oriented global warming containing sharing task and jumping task problems, student response predictions, and teacher anticipations have been created and tried out in a real classroom.
- The results of trying out the lesson design sharing and jumping tasks on the ESD-oriented topic of global warming show that students' collaborative skills emerged well.

References

1. Rahmat, A.; and Mutolib, A. (2016). Comparison air temperature under global climate change issue in Gifu city and Ogaki city, Japan. *Indonesian Journal of Science and Technology*, 1(1), 37-46.
2. Lestari, D.A.; Suwarma, I.R.; and Suhendi, E. (2024). Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics. *Indonesian Journal of Teaching in Science*, 4(1), 1-10.
3. Nurramadhani, A.; Riandi, R.; Permanasari, A.; and Suwarma, I.R. (2024). Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, 9(2), 261-286.

4. Asif, M.; Saleem, S.; Tariq, A.; Usman, M.; and Haq, R.A.U. (2021). Pollutant emissions from brick kilns and their effects on climate change and agriculture. *ASEAN Journal of Science and Engineering*, 1(2), 135-140.
5. Karmaker, R.; and Lemon, M.H.A. (2024). Is climate change a curse? Causing huge effect on various fields: An educational perspective. *Indonesian Journal of Teaching in Science*, 4(1), 85-96
6. Ibrahim, I.M.; Suryadi, K.; Darmawan, C.; and Nurbayani, S. (2024). Examining climate change issues for improving cross-generation awareness in 21st century agenda: A bibliometric approach. *ASEAN Journal for Science Education*, 3(2), 173-182
7. Ulaboevich, B.G. (2022). Improving the effectiveness of the method of conducting physical education classes for students of grades 5-9 in hot climates. *ASEAN Journal of Physical Education and Sport Science*, 1(1), 35-44.
8. Houghton, R.A. (2005). Aboveground Forest Biomass and the Global Carbon Balance. *Global Change Biology (2005),* 11, 945-958.
9. Yoro, K.O.; and Daramola, M.O. (2020). Chapter 1 - CO2 emission sources, greenhouse gases, and the global warming effect. *Advances in Carbon Capture*, 3-28.
10. Bhikuning, A.; and Senda, J.S. (2020). The properties of fuel and characterization of functional groups in biodiesel-water emulsions from waste cooking oil and its blends. *Indonesian Journal of Science and Technology*, 5(1), 95-108.
11. Kolakoti, A.; Kumar, A.V.; Metta, R.; Setiyo, M.; and Rochman, M.L. (2022). Experimental studies on in-cylinder combustion, exergy performance, and exhaust emission in a Compression Ignition engine fuelled with neat biodiesels. *Indonesian Journal of Science and Technology*, 7(2), 219-236.
12. Pebrianti, M.; and Salamah, F. (2021). Learning simple pyrolysis tools for turning plastic waste into fuel. *Indonesian Journal of Multidiciplinary Research*, 1(1), 99-102.
13. Maheshvari, R. (2022). Study on economic, sustainable development, and fuel consumption. *ASEAN Journal of Economic and Economic Education*, 1(1), 41-46.
14. Venkataraman, B. (2010). Education for Sustainable Development. *Environment: Science and Policy for Sustainable Development,* 51(2), 8-10.
15. Solihah, P.A.; Kaniawati, I.; Samsudin, A.; and Riandi, R. (2024). Prototype of greenhouse effect for improving problem-solving skills in science, technology, engineering, and mathematics (STEM)-education for sustainable development (ESD): Literature review, bibliometric, and experiment. *Indonesian Journal of Science and Technology*, 9(1), 163-190
16. Rasuman, M.A.; Nandi, N.; Astari, A.J.; and Ashie, A.B. (2024). Trends and networks in education for sustainable development (ESD): A bibliometric analysis using vosviewer. *Indonesian Journal of Multidiciplinary Research*, 4(1), 109-126.
17. Ekamilasari, E.; and Pursitasari, I.D. (2021). Students' critical thinking skills and sustainability awareness in science learning for implementation education for sustainable development. *Indonesian Journal of Multidiciplinary Research*, 1(1), 121-124.

18. Suryani, L.; and Hamdu, G. (2021). Education for sustainable development in science national exam questions of elementary school. *ASEAN Journal of Science and Engineering Education*, 1(1), 1-6.
19. Zandalinas, S.I.; Fritschi, F.B.; and Mittler, R. (2021). Global Warming, Climate Change, and Environmental Pollution: Recipe for a Multifactorial Stress Combination Disaster. *Trends in Plant Science*, 26(2), 588.
20. Mimura N. (2013). Sea-level rise caused by climate change and its implications for society. *Proceedings of the Japan Academy. Series B, Physical and biological sciences*, 89(7), 281-301.
21. Prowse, T.D.; Furgal, C.; Chouinard, R.; Melling, H.; Milburn, D.; and Smith, S.L. (2009). Implications of climate change for economic development in northern Canada: Energy, resource, and transportation sectors. *AMBIO: A Journal of the Human Environment*, 38(5), 272-281.
22. Ahima, R.S. (2020). Global warming threatens human thermoregulation and survival. *The Journal of clinical investigation*, 130(2), 559-561.
23. Gatta, S.A.; Ishola, N.A.; and Falobi, O.V. (2023). Evaluation of business education curriculum and 21st century entrepreneurial skills in business education undergraduates students. *ASEAN Journal of Economic and Economic Education*, 2(2), 105-114.
24. Bantilan, E.N. (2024). Teachers 21st century skills special program in sports curriculum. *ASEAN Journal of Physical Education and Sport Science*, 3(1), 27-34.
25. Fatimah, I.; Hendayana, S.; and Supriatna, A. (2018). Didactical design based on sharing and jumping tasks for senior high school chemistry learning. *Proceedings of the 4th International Seminar of Mathematics, Science and Computer Science Education*, Bandung, Indonesia, 1-7.
26. Le, H.; Janssen, J.; and Wubbels, T. (2018). Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration. *Cambridge Journal of Education*, 48(1), 103-122.
27. Silalahi, R. M. (2019). Understanding Vygotsky's zone of proximal development for learning. *Polyglot: Jurnal Ilmiah*, 15(2), 169-186.
28. Hidayat, R. Y.; Hendayana, S.; Supriatna, A.; and Setiaji, B. (2020, March). Identification of student's collaborative skills through learning sharing and jumping task on the topic of redox reactions. *Proceedings of the International Conference on Mathematics and Science Education 2019 (ICMScE 2019)*, Bandung, Indonesia,1-4.
29. Fibrianto, S.; Hendayana, S.; Supriatna, A.; and Oktasari, C. (2021). How Sharing and Jumping Task affect to student interaction in chemistry learning. *Proceedings of the 1st South East Asia Science, Technology, Engineering and Mathematics International Conference (SEA- STEM IC) 2020,* Indonesia, 1-8.
30. Asari, S. (2017). Sharing and jumping task in collaborative teaching and learning process. *DIDAKTIKA Jurnal Pemikiran Pendidikan* 23(2), 184-188.
31. Sari, E.M.; and Putri, R.I.I. (2020). Development of sharing task and jumping task in direct proportion using lesson study and PBL. *International Journal on Emerging Mathematics Education,* 3(2), 177-190.

32. Suryadi, D. (2013). Didactical design research (DDR) dalam pengembangan pembelajaran matematika. In *Prosiding seminar nasional matematika dan pendidikan matematika,* 1(1), 3-12.
33. Fujii, T. (2016). Designing and adapting tasks in lesson planning: a critical process of Lesson Study. *ZDM Mathematics Education* 48, 411-423.
34. Hobri, Ummah, I. K.; Yuliati, N.; Dafik. (2020). The effect of jumping task based on creative problem solving on students' problem solving ability. *International Journal of Instruction,* 13(1), 387-406.
35. Susetyarini, E.; Nurohman, E.; and Husamah, H. (2022). Analysis of students' collaborative, communication, critical thinking, and creative abilities through problem-based learning. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika,* 6(1), 33-42.
36. Margolis, A.A. (2020). Zone of proximal development, scaffolding and teaching practice. *Cultural-Historical Psychology*, 16(3), 15-26.
37. Amida, N.; Nahadi, N.; Supriyanti, F.M.T.; Liliasari, L.; Maulana, D.; Ekaputri, R.Z.; and Utami, I.S. (2024). Phylogenetic analysis of Bengkulu citrus based on DNA sequencing enhanced chemistry students' system thinking skills: Literature review with bibliometrics and experiments. *Indonesian Journal of Science and Technology*, 9(2), 337-354.
38. Francis, T.T.; and Baba, S.J. (2023). Effect of concept mapping teaching approach on students' academic performance in chemistry in senior secondary schools. *Indonesian Journal of Educational Research and Technology*, 3(1), 69-78.
39. Putri, S.R.; Hofifah, S.N.; Girsang, G.C.S.; and Nandiyanto, A.B.D. (2022). How to identify misconception using certainty of response index (CRI): A study case of mathematical chemistry subject by experimental demonstration of adsorption. *Indonesian Journal of Multidiciplinary Research*, 2(1), 143-158.
40. Bugarso, J.M.S.; Arcenas, G.L.; Galigao, J.M.; and Camarao, M.K.G. (2024). Difficulty of science pre-service teachers in their major courses (physics, biology, chemistry, earth science). *Indonesian Journal of Multidiciplinary Research*, 4(1), 145-154.
41. Ghartey, W.; Kumi, N.A.; Bunbun, D.U.; Fenuku, S.D.; and Ghartey, K.B. (2024). The effects of digital media instruction on senior high school students' performance in organic chemistry nomenclature. *Indonesian Journal of Teaching in Science*, 4(1), 97-108
42. Wirzal, M.D.H.; and Halim, N.S.A. (2022). Short play approach for analytical chemistry class. *ASEAN Journal of Science and Engineering Education*, 2(2), 163-168.