Global warming & climate change: integration of socio-scientific issues to enhance scientific literacy

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Abstract. Global warming and climate change are some of the greatest socio-scientific issues in recent decades. Many factors contribute to these issues, the footprint of human activities as well as natural phenomena. Human energy consumption in many sectors i.e food supply, livestock, industry, and transportation significantly increasing earth surface temperature average level and climate change. Various studies were carried out about global warming and climate change interdisciplinary. Integration of these socio-scientific issues into science learning as an effort to educate and enhance student environmental awareness and scientific literacy is necessary to do. Rational of this article is to studies global warming and climate change topics from integrative science context; biology (microbial activities, ruminants, and environmental impacts), chemistry (the various chemical reaction that causes greenhouse gases and global warming), and physics (temperature, heat, and global climate). This study is urgent because microbial activities that contribute into greenhouse gases releasing in ruminant enteric fermentation process haven’t included and connected yet in Indonesia’s science learning. Ruminant should be highlighted in these issues because Indonesia is an agricultural country which has enormous farmhouse area. In addition, students are expected to be able to solve problems and make the right decisions related to these issues. This article will discuss suggestion global warming and climate change topics in terms of microbial activities, ruminant and mitigation strategies to reduce GHG from livestock sector. This suggestion is expected to meet the Sustainable development goals.

1. Introduction

Global warming and climate change are the serious socio-scientific issues [1], [2] that should be concerned nowadays is linked each other and sometimes interchangeably used [3], [4]. Global warming term was associated with a raising up of global temperature level while climate change refers to the change of weather pattern and natural phenomena that are not linked to heat term [4]. Both of them are necessary to highlight because it is harmful to human life and ecosystem [5].

As the socio-scientific issues, global warming and climate change related to the controversial issues in society [1] and science problems rooted [6]. Dramatically changes in human life in many sectors since the industrial revolution regarding to the large amount of greenhouse gases as a main cause of increasing of the earth surface temperature. Carbon dioxide (CO₂) from fossil fuel combustion in transportation and industry [7], methane (CH₄) from ruminant in livestock[8], [9], and nitrous oxide (N₂O) comes from farming practices and chlorofluorocarbon are the main GHG [5].

Global climate change is a cross-disciplinary study that is one of the important topics in sustainable development goals (SDG) [10]. Relevant studies show that public global warming and climate change
knowledge impact to their decision making, start from farmers [11], stakeholders [12], and academic society [13]. Therefore, it is necessary to integrate these issues into educational system to prepare the well educated and society awareness that be able to solve these dilemma problems. In the context of academic society, students should promote to understand the key ideas of nature in some specific scientific issues and practices their knowledge to reach it [14].

Global warming topics had already included into VII grade current science curricula in Indonesia but it hasn’t addressed about microorganism activities and ruminants contexts in details yet. Pathogens microorganism have evolved and migrated from one geographic area to another caused by the changing of environmental habitat condition through global warming and climate change [15], [16]. Thus, science educator challenges to provide information about the new microbial illness that widely discussed i.e, Salmonella, Escherichia coli, and H1N1 virus [15]. In addition, their ubiquity and diversity make microorganisms responsible for the production and sink of GHG due to their essential role in biogeochemical cycles regulation and organic waste decomposition [17].

As an agriculture country, Indonesia farmhouse areas spread in many areas which are produce CH₄, CO₂, and N₂O as the main of GHG. Cows and other kinds of ruminants became a local commodity in many farmhouse areas. Ruminants digestive system produce amount of CH₄ gas to the atmosphere. A cow produce about 70-120 kg CH₄ annually from its enteric fermentation. Methanogens, an anaerobic microbes which is active in ruminant’s gut [18] contribute to the release of CH₄ (methane) [19] [20] which has a global warming potential (GWP) 21 times that of CO₂ [21]. Therefore, specific information about microbial activities in ruminant need to be explored integratively in the global warming and climate change context in science classroom in Indonesia. Microbes activity in ruminant guts need to be explored in order to improve students’ content knowledge ability and scientific literacy.

This issue needs to be highlighted especially for schools in rural or farmhouse areas, e.g Boyolali regency. It is because current Junior High School science curriculum in Indonesia is more emphasis on the discussion about fossil fuels combustion from the transportation and industrial sectors as GHG producers. In fact, the villagers tend to raise the livestock both on a small or large scale. Through this elaboration, especially for students in rural areas are expected to understand the effects and ways of reducing the amount of GHG from the livestock sector. Global warming and climate change topics will give the opportunity to engage students in solving problems, so they can use the science concepts into real world situation [22].

How to use science conceptual knowledge to make the best decision and solve the problem namely scientific literacy, one of the important science learning goals in 21st century. Observation, data collection, evidence evaluation and determine the certain approach to answer the scientific question promotes scientific literacy [23]. Scientific literacy plays a significant role in addressing the problem related to the scientific issues that widely debated in society[14]. Integration of global warming and climate change as socio-scientific issues in learning will accommodate scientific literacy. Scientific literacy will lead students to master the content knowledge as well as the environmental awareness. Scientific literacy becomes the top priority in science education to prepare the student who can survive in the moderns society issues [24]. Based on the problem stated, this paper would suggest integrative science curricula in global warming and climate change topics for students in VII grade which is oriented to the microbial activities in ruminant digestive system.

2. Discussion
Actually, the nature of climate was always changing to respond the changing of natural phenomena on the earth. But, now the climate is changing rapidly as a result of GHG releases, the most malignant of ecological footprint from human activities. Nature of these gases were to warm up the earth.

However, when the emissions are rised up, meanwhile the absorption reduced, the presence of GHG in atmosphere elevate than ever been recorded. According to the second report from the Intergovernmental Panel on Climate Change (IPCC), the risk of climate change will significantly
increase as global average temperatures reach 2° C [25], to be estimated that in 2100 will rise 2.9° C [26] and sea level has elevated annually by average 2.5 millimetres due to it [27].

Global warming and climate change will threat the Government's efforts to reduce poverty in Indonesia and achieve the Millennium Development Goals (MDGs) [26]. Responding to these global issues and as a follow up to the annual UN conference on climate change, at the end of 2015 the Paris Agreement was agreed which is aimed to maintain the global temperature of the century below 2°C and encourage efforts to limit it to 1.4°C above pre-industrial levels [7].

Nowadays, science educators challenge to devote a holistic and comprehensive explanation about these socio-scientific issues to increase students awareness and scientific literacy. Integrative explanation from interdisciplinary context helps students to understand these issues. Integrates socio-scientific issues into science education provide significant transformation in science learning [28]. Through socio-scientific issues, students get more opportunities to think and to be expected to be able to use their knowledge to face the problem that coming up. In hence, socio-scientific problems provide problem solving experiences for students, so they could think about alternatives mitigation strategies in regional, national and global context.

Global warming and climate change should be viewed from integrated science. Integrative approach helps students to understand about these controversial issues easier. Thus, curricula and teachers have to accommodate this integration in the science classroom. Educators should improve their pedagogical content knowledge to organize and serve these issues in better ways. Educators should be able to explain these phenomena from biology, chemistry and physics perspectives so that students have scientific experiences through interdisciplinary learning.

Biology subject is not only viewed as the environmental impact, microbial activities and ruminant topics but also meet the criteria to be major cause of global warming and climate change. As a cause, microorganism generate CH$_4$ according to the decomposition process of organic waste, such as ruminant manure and food waste. CH$_4$ and other GHG were anorganic substances closely related to biogeochemical cycles. Heat, temperature elevation and global climate are physics relates. All these topics should be described to connect each other in order to meet a comprehensive understanding. Figure 1 suggests the integrative approach illustration of science conceptual knowledge in global warming and climate change topics.

**Figure 1.** Integrated Approach of Global Warming and Climate Change
Table 1 Provide the suggestion of integrated approach of global warming and climate change for VII grade. The suggestion emphasizes the discussion of microbial activities, ruminant, greenhouse gases as well as the appropriate strategies to tackle these problems which is related to global warming. Through habituation to deal with socio-specific issues, students will be engaged in solving the problems wisely. The science concepts that they have acquired will be applied in order to solve problems both in the learning context and real-world situations.

| No. | Science Curricula in Global Warming Topics for VII grade | Current | Suggestion |
|-----|--------------------------------------------------------|---------|------------|
| 1.  | Global warming causes : Energi consumption, transportation sector, fossil fuel combustion, industrial sector, agriculture, rubbish burn | Global warming causes: Fossil fuel combustion, agriculture, live stock, ruminant digestive system, microbial activity in agricultural and live stock sector which is produce GHG. |
| 2.  | Global Warming Mechanism : Green house effect, warming the Earth | Global warming mechanism: temperature, heat, green house effect to warming the Earth |
| 3.  | GHG : CO₂, SO₂, CH₄, CFC, HFC, NO | GHG: CO₂, CH₄, N₂O, SO₂, CFC, Global Warming Potential (GWP), chemical reaction in ruminant enteric fermentation which is produce CH₄ |
| 4.  | Global Warming Impact : rapidly melting of polar ice, rising up the sea level, extreme climate change. | Global warming impacts: climate change, elevated of sea level, effect in living organism, impact in agriculture and farm house. |
| 5.  | Global warming solving ways: 3R, reducing the energy consumption, reboisation, use the bio-energy | Global warming solving ways: behavior change in 3R, reducing animal-derived food consumption, analyze and provide the strategies to reduce GHG release from farm house land. |

2.1. Microbial Activities
Why do microbes becoming important things which should be explored in science classrooms? Microorganisms are one of the major form of life on the earth. Their rapidly evolved make the revolutionary diversity that vastly exceeds that of all other organisms. They able to survived in the extreme condition [17]. Microbes are the main foundation of the biosphere [29]. Aerobic and anaerobic microbes are the main actor related to the biogeochemical cycles and support the sustainability of this planet. Their presence becoming important through their activities to the recycling of organic materials [17]. Microbes are the determinant of global warming and climate change related to their roles in GHG production [8], [30].

As the main cause of global warming and climate change, microbial activity in (1) enteric fermentation in ruminant, (2) biogeochemical cycles, and (3) recycling organic waste process (e.g. food waste, industrial waste, and manure) produce a large amount of GHG. In contrast, microbes has evolved rapidly due to the increase of global temperature and the change of their habitats condition. The pathogen microbes could threat the human health. The prevention and treatment techniques of new type of microbiall illness have to provide in the science classroom to address the disease conceptual knowledge understanding.

2.2. Enteric Microbial Fermentation in Ruminant
The ruminant stomach consists of four-chamber. The biggest compartment called rumen, the main digestive center which has the unique ecosystem [31]. Rumen ecosystem contains a biomass abundant of microorganism diversity, the combination of flagella protozoa, ciliated protozoa, amoeba, bacteria, and bacteriophages [30]. Each type has a specific function in degradation of the ruminant feed
nutritious (carbohydrate, fats and protein). Methanogen type (anaerobic bacteria and archae) ferment the fibrous food to produce volatile fatty acids as a main produce to serve energy and \( \text{CH}_4 \) as a by-product [30]–[32]. Enteric fermentation produced more than 85% of the total \( \text{CH}_4 \) from ruminant [33]. Anaerobic bacteria involved in enteric fermentation of glucose from plant starch. This process occurs under anaerobic conditions in the Embden-Meyerhof-Parnas pathways in the rumen. \( \text{CH}_4 \) formed as a result of \( \text{H}_2 \) production and \( \text{H}_2 \) elimination in this glycolysis process (see Figure 2) [34].

**Figure 2.** Embden-Meyerhof-Parnas pathways in the rumen to produce \( \text{CH}_4 \)[35]

Summarize of hydrogen production and hydrogen elimination reaction in glycolysis pathways described as follows [34]:

- **2\( H \) production reaction:**
  
  \[
  \text{Glucose} \rightarrow 2 \text{pyruvate} + 4\text{H} \quad \text{(Embden-Meyerhof-Parnas pathway)}
  \]

- **2\( H \) using reactions:**
  
  \[
  \text{Pyruvate} + H_2O \rightarrow \text{acetate} (C_2) + CO_2 + 2H
  \]

\[
\text{Pyruvate} + 4H \rightarrow \text{propionate} (C_3) + H_2O
\]

\[
2C_2 + 4H \rightarrow \text{butyrate} (C_4) + 2H_2O
\]

\[
CO_2 + 8H \rightarrow \text{methane} (\text{CH}_4) + 2H_2O \quad \text{(methanogenesis)}
\]

The fermentation reaction occurs due to microbial activities namely methanogenesis process. Methanogenic bacteria produce enzyme which is used as a catalyst in \( \text{CO}_2 \) reduction by \( \text{H}_2 \). The simple methanogenesis reaction shows in equation 6.

\[
\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O} \quad \text{(methanogenesis)}
\]

\( \text{CH}_4 \) from ruminant released to the atmosphere in the exhaling process and ruminating through nostrils or mouth [36]. Type and size of animal, as well as feed influence the emission of \( \text{CH}_4 \) [37]. The higher the fibre content in the feed, the lower the digestibility, but the \( \text{CH}_4 \) produce increasing [38].
2.3. Ruminant Impact on GHG Releases

Nature and anthropogenic activities generate GHG. Ruminant produce CO$_2$, N$_2$O and CH$_4$ in large amount. Ruminant stomach which is called rumen contains various kind of microbes. This very complex ecosystem contains methanogen related to CH$_4$ production that releases to the atmosphere from livestock subsector [30]. A cow by average produce about 70-120 kg CH$_4$ annually [20] which has a global warming potential (GWP) 21 times that of CO$_2$ [21]. However, this exact number is debated [9]. CH$_4$ is a by-product of fermentation of organic substances in the ruminant stomach [39].

Ruminant in the livestock production system (goat, dairy-cow, cattle, buffalo, sheep, etc) is one of primary contributor of GHG from agriculture sector [40]. Livestock system is responsible for 16% of the total GHG emission to the atmosphere. In 2015, beef cattle contributed 66.99% from total atmospheric GHG from livestock sector in Indonesia, followed by goat (8.38%), sheep (7.40%), buffalo (6.89%) and other animals like swine, broiler chicken, and horse [41]. In some specific livestock area in Indonesia, for example Boyolali Regency which well known with cattle product, GHG emission from livestock sector dominated by cattle farming (see Figure 3) [37]. Researchers use carbon footprint analysis to determine which livestock system is more productive and effective to reduce the required resources.

![Figure 3. GHG emission percentage from livestock in Boyolali Regency](image)

CH$_4$ emission contribution from livestock sector in Indonesia is 16.5% in 2012 [33], increased by 7% in 2010 and predicted will arrive at 58 % in 2030 [38]. The Indonesian government should focus on this sector management including food and manure [9]. Many food management system include diet manipulation i.e using plant bioactive compounds as feed additives [33] from leaves, olive cakes, tomatoes waste [40], coconut and fish oil [42]. Some mitigation strategies described in Table 2 could use to decrease methane emission from ruminant. As increasing of global demand for food supply from animal more than 2% by year [40], those management system strategies in Table 2 is urgent to do because it could reduce the environmental impacts from the emission rate of CO$_2$, CH$_4$, and N$_2$O. Therefore, the public should be promoted and are supported to reduce the animal-derived food consumption in their daily menus.
Table 2. Different mitigation strategies to reduce methane emission from ruminant [36], [37]

| No. | Strategies |
|-----|------------|
| 1   | An enterprise of livestock population reducing |
| 2   | Select the superior genetic animals which produce low CH\textsubscript{4} |
| 3   | Feeding strategies with nutritious food and diet manipulation |
| 4   | Fostering the grassland management system |
| 5   | Ruminant healthy maintain through veterinary check regularly |
| 6   | Improvement of the doses of concentrate |
| 7   | Diet manipulation through the additive feed from saponin containing plants, tanning containing plants or other local food industry |
| 8   | Defaunation and rumen microbial intervention |
| 9   | Reducing the demand of animal-derived food |
| 10  | Use advanced technology to reduce CH\textsubscript{4} emission, for example recombinant technology and immunization |
| 11  | GHG emission inventory check regularly |

2.4. GHG trapping heat and Its impact to Global Warming

Global warming is the result of an imbalance between the heat received by the Earth and radiated back into space. Electromagnetic waves from the sun radiated to the Earth and only a few types of waves which is able to penetrate the atmosphere, namely visible light and long waves or global irradiance [43]. GHG trap heat from sun and warming up the earth. The main GHG has each potential in trapping heat which is called GWP (see Table 3). Concentration GHG in the atmosphere used to heat the planet by trapping radiation from the sun [44].

Table 3. GWP of the main GHG [36]

| GHG        | Chemical Formula | Radiative efficiency (W/m\textsuperscript{2} ppb) | GWP | Lifetime (years) |
|------------|------------------|-----------------------------------------------|-----|-----------------|
| Carbon dioxide | CO\textsubscript{2} | \(1.4 \times 10^{-5}\) | 1   | Up to 100 years |
| Methane    | CH\textsubscript{4} | \(3.7 \times 10^{-4}\) | 21  | 12              |
| Nitrous dioxide | N\textsubscript{2}O | \(3.03 \times 10^{-3}\) | 310 | 114             |

Naturally, GHG is a good insulator which keeps Earth's atmosphere not interact directly with space and keep this planet hot (see Figure 4). It is widely discussed about the terms of GHG as Earth’s blanket. Anthropogenic activities propose GHG that distributed globally (CO\textsubscript{2} and CH\textsubscript{4}) and make the Earth surface temperature increase annually than that of the pre-industrial era. CO\textsubscript{2} gases trap heat in whole world in daytime and night. CO\textsubscript{2} and other GHG reducing technology need to apply to maintain the Earth's temperature.

The global climate change occurs because of the rise of Earth surface temperature significantly and many other factors. Stop the buildup atmospheric GHGs is the most possible and safest strategy for fighting climate change. This alternative seems too hard to attain in a short time while the dangers are mounting. The consequence of this problems will cause pivotal impact in society and economic if the mitigation strategy not taken as soon as possible [45]. Policy maker, other decision maker and public should take an action to face the problem about global warming and climate change. Improving the livestock management system is one of the best strategies that should be emphasized to solve global warming and climate change.
2.5. Socio-Scientific Issues to Enhance Scientific Literacy

Public awareness about socio-scientific issues is an essential background to adapt to current issues and related problems. Science curriculum in Indonesia mandate to propose opportunities to enhance students thinking ability. They should be able to use their scientific knowledge to make ideas, argument and make a decision in science issues that affecting society [46]. Some previous researches show that students have difficulties according to their inability to use their scientific conceptual knowledge to make a decision on social issues [6], [47]. The ability to solve the problem use their scientific knowledge in real-life situation namely scientific literacy. The term of scientific literacy is the main goal of science education nowadays and broadly covers the integration of natural science with social science, mathematics, engineering, and technology [48].

Development of students ability to comprehensive understanding, discussed, defend their argument and decision making regarding the socio-scientific issues are important to promote scientific literacy [1], [6]. Romine et al. [28] classified vision to subsumed the ideas of scientific literacy into two main categories. Vision 1 associated with the scientific knowledge understanding that not related to another discipline perspective. In contrast, Vision 2 promotes student engagement in the scientific concept that connected to societal issues. This vision is more externally oriented.

Vision 2 could attain by socio-scientific issues approach. Students experience in new and controversial issues will cultivate the development of the scientific literacy to prepare educated and characterized citizenship [49]. Socio-scientific issues could serve in interdisciplinary scenario. However, relevant study show that students have difficulties to use the interdisciplinary concept for problem solving in daily life issues [50]. In the context of global warming and climate change issues that broadly discussed, the teacher should provide the integrative approach scenario. Discussion and debate session in global warming and climate change topics will enhance the student's performance in defending their arguments about strategies to (1) microbial activities connections with ruminant, (2) reduce atmospheric GHG, (3) promotes effective feeding for ruminant animals and (4) adaptation to

Figure 4. Earth’s annual global mean energy budget [43]
global warming. In hence, students’ scientific literacy should assess by teachers to categorized their scientific literacy level i.e nominal, functional, conceptual and procedural or multidimensional [50].

Through these socio-scientific integration, the student will reach a comprehensive understanding of their real world problems. Thus, student participation in the interdisciplinary learning scenario will impact on their problem solving skills. Socio-scientific issues integration leads to reach the SDG.

3. Conclusion

Global warming and climate change as a widely discussed in society are a pivotal issues to integrates into science learning. Educators should provide holistic and comprehensive matter from an integrative science perspective. Student will reach a comprehensive understanding of their real world problems from physics, chemistry and biology. This suggestion science curricula that serve in the interdisciplinary approach in the science classroom will enhance scientific literacy and argumentation skills because they’re engaged to give the strategies to solve the problems related GHG reducing from livestock sector. Ruminant and livestock will provide the contextual learning for student Indonesia especially in rural areas. So, the next research can apply and test the effectiveness of this suggestion curricula into science learning to improve student scientific literacy.

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