Vol 14(1) (2025): 64-77
DOI: http://dx.doi.org/10.24235/sc.educatia.v14i1.19470

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

http://www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

Analysis of Understanding the Concept of Environmental Pollution for Middle School and High School Students using a Cross-Sectional Approach

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article info

Article history:
Received: 01 May 2025
Received in revised form: 08 May 2025
Accepted: 20 June 2025
Available online: 30 June 2025

Keywords:
Environment polluted
Conceptual understanding
Science education
Learning strategies
Cognitive development

abstract

Environmental pollution is a concept-based science learning material related to life and the environment. Students' conceptual understanding of environmental pollution is very low because they often memorize without understanding the deeper meanings of the concepts they study. This study aims to analyze the conceptual understanding of tenth-grade high school students and seventh-grade junior high school students regarding environmental pollution. The method used in this study was a cross-sectional survey comprising the preparation stage of creating an online questionnaire with 4 questions, the implementation stage of sending the questionnaire, and the data analysis stage of student responses. Based on the data analysis, some tenth-grade high school students and seventh-grade junior high school students still have limited conceptual understanding because they focus on textbook concepts without understanding their meanings and relationships to environmental issues. However, some high school students already have a broad conceptual understanding. This indicates that the higher the level of education, the more important concepts emerge. The problems faced by junior high school students and some high school students can be overcome by choosing a learning strategy based on direct environmental practice so that students not only understand the concepts but also develop a sense of concern for the environment.

1. Introduction

Science and technology are experiencing rapid development in the current era of globalization, particularly in education. Education is crucial for improving the quality of human resources so they can compete in this era. Therefore, students must possess a quality education that encompasses knowledge, skills, creativity, independence, and a sense of responsibility to themselves and society. The most important aspect of education for students is the ability to understand concepts. Conceptual understanding is the ability of students to write and convey in their own words all knowledge gained, based on what they read and what they learned from teacher explanations or reading sources. This aligns with the opinion of Kristanti and Isnarto (2019) that conceptual

understanding is an important skill for students, including understanding science learning concepts (Setiani et al., 2022).

Science learning is a subject closely related to human life. Students often misunderstand scientific concepts, believing they are easy when they are difficult. Science learning is much easier when students have a strong understanding of science concepts. However, if students frequently misunderstand science concepts, they will have difficulty understanding subsequent science concepts (Alighiri et al., 2018). One of the science learning materials is environmental pollution. Understanding the concept of environmental pollution is crucial because it is closely related to life and the environment. Therefore, students must understand the definition, causes, impacts, and prevention efforts for environmental pollution. Understanding the concept of environmental pollution aims to foster students' concern for the environment by instilling a sense of environmental stewardship. Real-world experiences significantly influence students' conceptual understanding. By understanding the concept of environmental pollution, students are expected to develop the best solutions to anticipate future environmental pollution problems.

Several previous studies have shown that students' conceptual understanding in science learning is still highly variable and suboptimal. Nisa' et al. (2022) found that students' conceptual understanding was relatively low for topics such as pressure, hydrostatic pressure, Pascal's law, and Archimedes' principle. Furthermore, according to Ainul et al. (2025), students' conceptual understanding of science material was classified as low, as determined by descriptive analysis, with a maximum score of 70, a minimum of 24, and an average of 46.67.

These findings indicate that students' conceptual understanding still faces challenges across various levels and subject areas. Based on the findings above, conceptual understanding is the primary focus of this study, as the concept of environmental pollution is a science topic taught in seventh-grade junior high school and in tenth-grade senior high school. Seventh-grade junior high school and tenth-grade senior high school students study environmental pollution in the first semester, referring to existing competencies at school.

Research on the conceptual understanding of environmental pollution at the junior high and senior high school levels has not been fully explored by previous researchers. Developing a conceptual understanding of environmental pollution is crucial for creating a quality environment. The learning process is not only acquired through educational institutions but also begins in the surrounding environment. The environment is a learning process that can change a person's behavior and mindset (Sinta et al., 2021). The relationship between the concept of environmental pollution in seventh-grade junior high school and tenth-grade senior high school students represents an improvement on previous research. Previous research examined only the relationship between environmental knowledge and students' concern for the environment, without assessing students' conceptual mastery of environmental pollution or differences in conceptual understanding between students who have and have not studied environmental pollution.

Teachers can understand students' cognitive development and choose appropriate learning strategies to facilitate students' understanding of the concepts taught, especially environmental pollution. This study can also serve as an additional reference for researchers examining students' conceptual understanding more deeply. This can be beneficial in this study. The innovation in this study is a cross-sectional analysis of the understanding of seventh-grade junior high school students and tenth-grade senior high school students regarding the definition, causes, impacts, and methods for mitigating environmental pollution (Rusyati, 2021). Cross-sectional research has so far described students' conceptual understanding of material across various educational units, including environmental pollution. This study describes educational background, caring attitudes, and learning resources that can influence students' concepts of environmental pollution. This study describes the concepts of environmental pollution and the number of concepts found in each questionnaire question distributed to seventh-grade junior high school students and to tenth-grade senior high school students.

2. Method

A cross-sectional survey is the research design used to collect data from a sample. A cross-sectional design was chosen to assess a population through a sample, using students' levels of academic integrity as the research variable, while also measuring the need for educational services related to programs, school facilities, or involvement in the school or community (Creswell & Plano, 2012).

This research consisted of several stages: preparation, implementation, and data analysis. The preparation stage began with the development of an open-ended questionnaire on environmental pollution. The next stage was the implementation stage, which involved distributing the questionnaire online to participants. Participants were strongly encouraged to be honest when completing the questionnaire, stating that their answers must be based on their own knowledge and will not affect their report card grades. Therefore, they were not permitted to consult books or other learning resources, such as the internet, to find answers.

The final stage was data analysis. In this stage, the researcher compiled data from the questionnaire responses by coding students' conceptual responses and presenting the results as percentages for the two groups. The coding process was applied to both questions and answers. The coding for the questions included the definition of pollution (A), causes of pollution (B), impacts of pollution (C), and solutions to pollution (D), while the coding for the student data answers was A1 and so on, B1 and so on, C1 and so on, D1 and so on. After data analysis, all concepts were tallied. Tally marks are manual calculations using five lines, and so on. The research process began with creating open-ended questions and entering the question data into a Google Form application to convert it into an online questionnaire. The questionnaire link was then distributed online to seventh-grade students at SMP Ar-Risalah and to tenth-grade students at SMA 2 Rambatan Tanah Datar.

The sampling technique for this study used cluster sampling, a method based on naturally formed groups or clusters, in this case, classes (Mukhlis et al., 2024). The research was conducted online at two different schools: SMP Ar-Risalah Padang and SMA 1 Batipuh. Seventh-grade students at Ar-Risalah Junior High School and tenth-grade students at Batipuh 1 Senior High School were enrolled in an environmental study program, studying environmental pollution during the odd semester of the 2024-2025 academic year. The researcher sent research permit letters from the faculty to the target schools and communicated with science teachers at each school to distribute questionnaire links to students in their classes.

Selecting classes as sample units was considered more practical and efficient for reaching respondents, given limited physical access to the research locations. Furthermore, this technique aligned with the school's organizational structure and formal communication procedures, enabling effective collaboration between the researcher and the school.

3. Result and Discussion

This study was conducted to determine students' conceptual understanding of environmental pollution material by giving four online questions to seventh-grade junior high school students and tenth-grade senior high school students. Conceptual understanding in students is very important, so that students not only know the material being studied but also understand it (Christner et al., 2020). Understanding the concept of environmental pollution is crucial for protecting the environment, especially the surrounding environment (Hartmann et al., 2022). Students often find environmental pollution material very easily, even though it is contextual and presents many conceptual problems (Aseptianova, 2019). This study aimed to determine students' conceptual understanding of environmental pollution. The distribution and percentage of seventh-grade and tenth-grade junior high school students' conceptual understanding of the definition of environmental pollution are shown in Table 1.

Table 1. Distribution and percentage of conceptual understanding of seventh grade junior high school students and tenth grade senior high school students regarding the definition of environmental pollution

Code	Concept	High School		Junior High School	
		F	%	F	%
A1	Environment	66	27.5	67	25.97
A2	Rubbish	0	0	15	5.81
A3	Nature	12	5	13	5.04
A4	Polluted	0	0	39	15.12
A5	Foreign Objects	0	0	1	0.39
A6	Damage	42	17.5	52	20.15
A7	Process	27	11.25	0	0
A8	Change	13	5.41	0	0
A9	Quality	9	3.75	0	0
A10	Balance	6	2.5	0	0
A11	Bacteria	1	0.42	0	0
A12	Waste	28	11.67	8	3.1
A13	Human Activities	36	15	63	24.42
Total		240	100	258	100

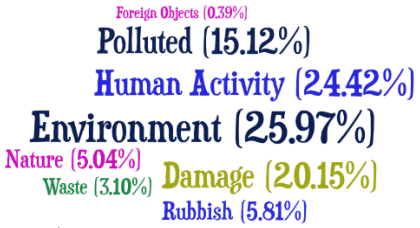
Table 1 shows differences in conceptual characteristics in how 10th-grade high school students and 7th-grade junior high school students define environmental pollution. In general, the dominant concepts used by 10th-grade high school students and 7th-grade junior high school students were "Environment," "Damage," and "Human Activity." Based on these concepts, 10th-grade high school students and 7th-grade junior high school students' initial understanding of pollution focused on environmental conditions, the damage caused, and human activity as the primary cause.

In terms of the depth and type of concepts emerging, there were significant differences between the two levels of education. 7th-grade junior high school students used more concrete, descriptive concepts, such as "Foreign Object," "Polluted," and "Waste," indicating that junior high school students tended to rely on visual representations and physical forms of environmental pollution. Meanwhile, 10th-grade high school students tended to use more abstract and systemic concepts such as "process," "quality," and "balance." 10th-grade high school students began to understand environmental pollution as a process that affects environmental quality and can lead to ecosystem imbalance. More specifically, the concept of "bacteria" was found among the answers of 10th-grade high school students, indicating a broadening of understanding of biological pollution.

Several keywords were not found among junior high school students but were present among high school students, and vice versa. Three keywords were not found among high school students: "waste," "polluted," and "foreign object." Five keywords were not found among middle school students: "process," "change," "quality," "balance," and "bacteria." This suggests that junior high school students' concepts are still centered on a few key terms and are not evenly distributed across other concepts.

Based on this issue, it can be inferred that junior high school students' conceptual representations of environmental pollution remain limited to direct, frequent experiences in their daily lives. Meanwhile, 10th-grade high school students' conceptual understanding is more diverse, not solely focused on keywords, and reflects a more connected cognitive structure among concepts. Student Conceptual Perceptions of the Definition of Environmental Pollution Based on Qualitative Frequency are shown in Figure 1.

(a) 10th High School Students of Grade



(b) 7th Grade Junior High School Students

Figure 1. Students' concept perception of the definition of environmental pollution based on frequency qualitatively

Figure 1 shows students' conceptual perceptions of the definition of environmental pollution, based on qualitative frequencies presented as word art. Words in the word art are displayed based on percentage frequency and different font sizes. In the word art, there is a striking difference between the conceptual representations of 10th-grade high school students and 7th-grade junior high school students.

In the 10th-grade high school students' word art, 10 keywords were identified, with the concept of "environment" being the most dominant at 27.50%. In addition to the concept of environment, other concepts included "damage" (17.50%), "human activity" (15%), "waste" (11.67%), "process" (11.25%), "change" (5.41%), and relatively few concepts were found: "nature" (5%), "quality" (3.75%), "balance" (2.50%), and "bacteria" (0.42%). Although high school students' concepts in defining pollution predominantly centered on the environment and its impacts, their word art visualizations also demonstrated a diversity of more complex concepts and reflected a more abstract level of thinking, including "process," "change," "quality," "balance," and "bacteria."

The presence of these diverse concepts indicates that tenth-grade high school students have begun to understand environmental pollution as a dynamic system involving change, environmental degradation, and disruption of ecological balance. High school students are at the formal-operational stage of cognitive development (Piaget, 1972). The formal-operational level means students can generalize, see relationships among concepts, and understand phenomena systematically. Seventh-grade junior high students' word art exhibited a distinct pattern. Eight key words were found in the junior high students' word art. The dominant concept, based on font size, was "environment" at 25.97%, followed by "human activity" at 24.42%, "damage" at 20.15%, "pollution" at 15.12%, "rubbish" at 5.81%, "nature" at 5.04%, "waste" at 3.10%, and a relatively small number of keywords, namely "foreign objects" at 0.39%.

Based on the concepts found, junior high school students' tendency towards concepts still relies on memorization and focuses more on textbook words without understanding the concepts in their own terms. This condition aligns with the cognitive development of junior high school students, who are still in the concrete operational stage (Piaget, 1972). At this stage, students tend to understand concepts through real objects and direct experience but have difficulty connecting the information they obtain to more complex causal structures. Furthermore, a memorization-focused approach also limits students' conceptual understanding. The distribution and percentages of conceptual understanding among seventh- and tenth-grade junior high school students regarding the causes of environmental pollution are shown in Table 2.

Based on the data shown in Table 2, there are differences in the characteristics of conceptual understanding between 10th-grade high school students and 7th-grade junior high school students in identifying the causes of environmental pollution. In high school students, the most frequently occurring concepts of causes of environmental pollution were "waste" at 29.79% and "littering" at 26.81%. In addition to these two concepts, there were other concepts, including "pollutants" at 9.79%, "human negligence" at 8.51%, "population density" at 5.53% and "natural factors" at 6.38%. High school students also mentioned more complex concepts of causes of environmental pollution

such as "exploitation" at 3.83%, "grilling" at 2.55%, and "less self-awareness" at 6.81%. Meanwhile, in junior high school students, the most dominant concepts of causes of environmental pollution were "littering" at 34.09% and "human negligence" at 31.25%. Other representations of pollution causes were more personal and moralistic, such as "don't care" (7.39%), "not responsible" (1.7%), and concrete actions such as "cutting down trees" (2.84%). Other concepts included "waste" (13.64%), and "pollutants" (9.09%).

Table 2. Distribution and percentage of conceptual understanding of seventh grade junior high school students and tenth grade senior high school students about the causes of environmental pollution

Code	Concept	High School		Junior High School	
		F	%	F	%
B1	Waste	70	29.79	24	13.64
B2	Pollutants	23	9.79	16	9.09
B3	Population Density	13	5.53	0	0
B4	Natural Factors	15	6.38	0	0
B5	Human Negligence	20	8.51	55	31.25
B6	Not Responsible	0	0	3	1.7
B7	Don't Care	0	0	13	7.39
B8	Less Self-Awareness	16	6.81	0	0
B9	Cutting Down Tress	0	0	5	2.84
B10	Grilling	6	2.55	0	0
B11	Exploitation	9	3.83	0	0
B12	Littering	63	26.81	60	34.09
Total		235	100	176	100

These findings indicate that high school students tend to have a more diverse and systemic understanding of the causes of environmental pollution, including structural factors and human behavior within a broader social context. Meanwhile, junior high school students understand pollution causes more as direct actions such as littering or neglecting the environment. This phenomenon suggests that cognitive development and learning experiences influence how students understand cause-and-effect relationships in environmental issues.

Junior high school students' conceptual understanding emphasized individual moral aspects, such as "don't care," "not responsible," and "cutting down trees," reflecting a more normative than analytical approach to learning. This may be due to a learning process that does not involve much exploration of systemic factors or complex cause-and-effect relationships. Furthermore, several concepts lacking academic vocabulary needed to understand environmental issues contextually were not found in junior high school students, such as "population density" and "natural factors." Therefore, learning at the junior high school level needs to be more directed at developing critical thinking skills and the ability to construct a deeper understanding of causal concepts about environmental phenomena.

Data analysis in the table reveals several keywords found in junior high school students but not in high school students, and vice versa. Five keywords were not found in junior high school students: "population density," "natural factors," "less self-awareness," "grilling," and "exploitation." Three keywords were not found in high school students: "not responsible," "don't care," and "cutting down trees." This suggests that high school students view pollution not only from physical actions but also from the underlying social and ecological conditions. Differences in age and education level between tenth-grade and seventh-grade high school students also influence students' causal and systemic thinking skills in identifying the causes of environmental pollution. Student Perceptions of the Causes of Environmental Pollution Based on Qualitative Frequency can be seen in Figure 2.

(a) 10th High School Students of Grade *(b) 7th Grade Junior High School Students*

Figure 2. Students' conceptual perception of the causes of environmental pollution based on frequency qualitatively

Figure 2 qualitatively demonstrates students' conceptual perceptions of the causes of environmental pollution by frequency. The junior high school students' word art displays keywords in sizes proportional to their frequency. Seven keywords were found in the word art displayed for seventh-grade junior high school students. The most dominant keywords are displayed in order of font size and attractive colors. At the junior high school level, the most dominant keyword is "Littering" with the highest font size, followed by "human negligence," "waste," "pollutants," and "don't care." The smaller font size and frequency distribution are "cutting down trees" and "not responsible." Meanwhile, nine keywords were found in the high school students' word art. The most dominant keyword, with the largest font size, is "waste," followed by "littering," "pollutants," "human negligence," "less self-awareness," and "natural factors." The least frequent keywords are "population density," "exploitation," and "grilling."

The differences found between seventh-grade junior high school students and tenth-grade senior high school students in understanding the causes of environmental pollution are clearly visible in the displayed word art. The bar chart provides information reinforced by qualitative data in the word art. Students' ability to integrate theoretical knowledge increases with increasing educational level. These results demonstrate the importance of a learning approach that encourages students to think critically and systematically, rather than relying solely on memorization. The distribution and percentage of conceptual understanding of seventh- and tenth-grade junior high school students regarding the impact of environmental pollution are shown in Table 3.

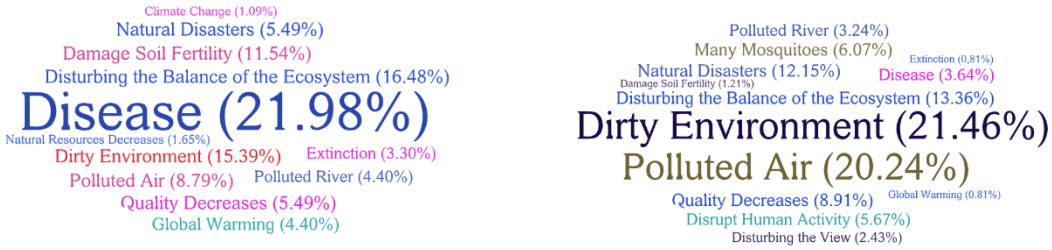
Table 3 shows the differences in conceptual characteristics of the answers given by 10th grade high school students and 7th grade junior high school students regarding the impact of environmental pollution. Based on the data, it can be seen that the highest percentage distribution is "disease" at the high school level at 21.98% followed by "dirty environment" at the junior high school level at 21.46%, the concept of "polluted air" at the junior high school level at 20.24%, "disturbing the balance of the ecosystem" at the senior high school level at 16.48 then followed by "dirty environment" at the junior high school level at 15.39%. Senior high school students more often associate the impact of environmental pollution with health and the ecosystem as a whole. This is reflected in the high percentage of each concept, including "disease" (21.98%) and "disturbing the balance of the ecosystem" (16.48%). Meanwhile, the concepts of "dirty environment" (15.39%) and "damage soil fertility" (11.54%) also accounted for significant proportions, indicating that high school students tend to view pollution in the context of environmental quality and the balance of nature.

Table 3. Distribution and percentage of conceptual understanding of seventh grade junior high school students and tenth grade senior high school students on the impact of environmental pollution

Code	Concept	High School		Junior High School	
		F	%	F	%
C1	Dirty Environment	28	15.39	53	21.46
C2	Polluted Air	16	8.79	50	20.24
C3	Disturbing The Balance Of The Ecosystem	30	16.48	33	13.36
C4	Damage Soil Fertility	21	11.54	3	1.21
C5	Disease	40	21.98	9	3.64
C6	Quality Decreases	10	5.49	22	8.91
C7	Natural Disasters	10	5.49	30	12.15
C8	Global Warming	8	4.4	2	0.81
C9	Disrupt Human Activity	0	0	14	5.67
C10	Polluted River	8	4.4	8	3.24
C11	Extinction	6	3.3	2	0.81
C12	Many Mosquitoes	0	0	15	6.07
C13	Natural Resources Decreases	3	1.65	0	0
C14	Climate Change	2	1.09	0	0
C15	Disturbing The View	0	0	6	2.43
Total		182	100	247	100

In contrast, junior high school students more frequently mentioned the impacts of environmental pollution based on everyday experiences. The concepts of "dirty environment" (21.46%) and "polluted air" (20.24%) were the most frequently mentioned concepts, followed by "natural disasters" (12.15%) and "disturbing the balance of the ecosystem" (13.36%). Unfortunately, junior high school students quite frequently mentioned "many mosquitoes," with a percentage of 6.07%, as an impact. Although this concept did not appear in the responses of 10th-grade high school students, junior high school students were able to relate pollution to concrete, direct experiences in everyday life, such as the presence of mosquitoes or a dirty environment. Overall, the data in Table 3 indicates that the higher a student's education level, the more complex their understanding and connection of the impacts of environmental pollution to various aspects of life.

In addition, based on the percentage data, there are several striking conceptual differences between grade X high school students and grade VII junior high school students, such as concepts that are not found in grade X high school students but are found in grade VII junior high school students and vice versa. Concepts that are not found in grade VII junior high school students are "natural resources decreases" and "climate change". Meanwhile, concepts that are not found in grade X high school students are "disrupt human activity", "many mosquitoes", and "disturbing the view". This reflects that grade X high school students have begun to associate environmental pollution with environmental issues and are able to think about the long-term impacts that occur, while junior high school students tend to mention concepts that are still everyday or based on experience. Student Concept Perceptions about the Impact of Environmental Pollution Based on Qualitative Frequency can be seen in Figure 3.



(a) 10th High School Students of Grade *(b) 7th Grade Junior High School Students*

Figure 3. Students' conceptual perception of the impact of environmental pollution based on frequency qualitatively

Figure 3 shows students' conceptual perceptions of the impacts of environmental pollution based on qualitative frequency. Word art depicts the most dominant keywords at both levels of education. Word art for high school students shows that the most dominant concept with the largest font size is "disease" at 21.98%. Twelve keywords were found in high school students' word art, including "disease" (21.98%), "disturbing the balance of the ecosystem" (16.48%), "dirty environment" (15.39%), "damage soil fertility" (11.54%), "polluted air" (8.79%), "natural disaster" (5.49%), "quality decreases" (5.49%), "polluted rivers" (4.40%), "global warming" (4.40%), "extinction" (3.30%), "natural resources desreases" (1.65%), and "climate change" (1.09%).

Meanwhile, in seventh-grade junior high school students' word art, the most dominant concept was "dirty environment" (21.46%). Thirteen keywords were found in junior high school students' word art, including "dirty environment" (21.46%), "polluted air" (20.24%), "disturbing the balance of the ecosystem" (13.36%), "natural disaster" (12.15%), "quality decreases" (8.91%), "many mosquitoes" (6.07%), "disrupt human activity" (5.67%), "disease" (3.64%), "polluted river" (3.24%), "disturbing the view" (2.43%), "damage soil fertility" (1.21%), "global warming" (0.81%), and "extinction" (0.81%).

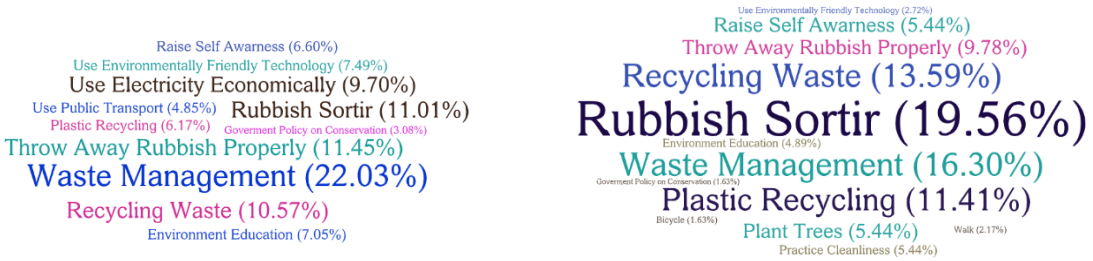
The word art presented demonstrates that high school students can recognize the various impacts of environmental pollution, with a focus on health, ecosystem balance, and overall environmental degradation. Meanwhile, the art of words in junior high school students shows that junior high school students are still low in understanding global and long-term issues related to environmental pollution, and junior high school students' conceptual understanding is very close to everyday life, but still needs to be strengthened in aspects of ecological and global impacts. The distribution and percentage of conceptual understanding of seventh and tenth-grade junior high school students regarding environmental pollution solutions are shown in Table 4.

Table 4 shows the differences in conceptual characteristics of the answers given by 10th-grade high school students and 7th-grade junior high school students regarding solutions to environmental pollution. The table shows the diversity of concepts for addressing environmental pollution. The most dominant concept in the bar chart is "waste management", with 22.03% of the concepts discussed at the high school level, followed by "waste sortir" with 19.56% of the concepts discussed at the junior high school level, "waste management" with 16.30% of the concepts discussed at the junior high school level, and "recycling waste" with 13.59% of the concepts discussed at the junior high school level. In general, the concept of "waste management" is the most dominant concept among both 10th-grade high school and 7th-grade junior high school students. This indicates that waste management has become a relatively familiar topic at both levels of education, although high school students' conceptual understanding of this issue as a solution to environmental pollution is stronger than that of junior high school students. In contrast to 10th-grade high school students, 7th-grade junior high school students more often mentioned "waste sorting" as a solution to environmental pollution than senior high school students. This reflects the emphasis on home or school waste-sorting practices, which are more concrete and relevant to the everyday experiences of junior high school students.

Table 4. Distribution and percentage of conceptual understanding of seventh grade junior high school students and tenth grade senior high school students regarding environmental pollution solutions

Code	Concept	High School		Junior High School	
		F	%	F	%
D1	Waste Management	50	22.03	30	16.3
D2	Rubbish Sortir	25	11.01	36	19.56
D3	Recycling Waste	24	10.57	25	13.59
D4	Plastic Recycling	14	6.17	21	11.41
D5	Use Public Transport	11	4.85	0	0
D6	Walk	0	0	4	2.17
D7	Bicycle	0	0	3	1.63
D8	Plant Trees	0	0	10	5.44
D9	Use Electricity Economically	22	9.7	0	0
D10	Raise Self-Awareness	15	6.6	10	5.44
D11	Practice Cleanliness	0	0	10	5.44
D12	Throw Away Rubbish Properly	26	11.45	18	9.78
D13	Environment Education	16	7.05	9	4.89
D14	Government Policy On Conservation	7	3.08	3	1.63
D15	Use Environmentally Friendly Technology	17	7.49	5	2.72
Total		227	100	184	100

The concept of "recycling waste" was a prominent solution among both 10th-grade and 7th-grade junior high school students, and the concept of "plastic recycling" was more common among 7th-grade junior high school students than 10th-grade senior high school students. Regarding emission reduction, senior high school students appeared to be more aware of the importance of using public transportation than junior high school students, but junior high school students were more likely to mention the concepts of "walk," "bicycle," and "plant trees." This imbalance may indicate that junior high school students tend to approach environmental pollution from a simple, practical, personal perspective, while senior high school students begin to consider systemic and collective solutions. Interestingly, the concept of "using electricity economically" was quite high among senior high school students, but not mentioned at all among junior high school students. This suggests that senior high school students have a deep conceptual understanding of the relationship between energy consumption and environmental impact. Some concepts were found in 10th-grade senior high school students but not in 7th-grade junior high school students, and vice versa. Concepts not found at the high school level include "practicing cleanliness," "planting trees," "bicycle," and "walking". Concepts not found at the junior high school level include "using public transport" and "using electricity economically." Based on this, the concepts found are aligned with students' cognitive development. students' conceptual perceptions of environmental pollution solutions based on qualitative frequency are shown in Figure 4.



(a) 10th High School Students of Grade *(b) 7th Grade Junior High School Students*

Figure 4. Students' perception of environmental pollution solutions based on frequency qualitatively

Figure 4 shows students' perceptions of environmental pollution solutions based on qualitative frequency. High school students' word art shows that the most dominant keyword with a relatively larger font size is "waste management" at 22.03%. In high school students' word art, 11 keywords were found, namely "waste management" at 22.03%, "throw away rubbish properly" at 11.45%, "rubbish sortir" at 11.01%, "recycling waste" at 10.57%, "use electricity economically" at 9.70%, "use environmentally friendly technology" at 7.49%, "environment education" at 7.05%, "raise self-awareness" at 6.60%, "plastic recycling" at 6.17%, "use public transport" at 4.85%, and "government education" at 3.08%. Meanwhile, word art in junior high school students with larger letters is found in the keyword "rubbish sortir" at 19.56%. Word art of junior high school students was found to have 13 keywords including "rubbish sortir" at 19.56%, "waste management" at 16.30%, "recycling waste" at 13.59%, "plastic recycling" at 11.41%, "throw away rubbish properly" at 9.78%, "raise self awareness" at 5.44%, "plant trees" at 5.44%, "practice cleanliness" at 5.44%, "environment education" at 4.89%, "use environmentally friendly technology" at 2.72%, "walk" at 2.17%, "bicycle" at 1.63% and "government policy on conservation" at 1.63%.

Based on the analysis of student response data, the bar chart provides a detailed qualitative discussion of the frequency of emerging concepts, while the word art displays collective and visual perceptions of the concepts. The combination of the bar chart and word art shows that 10th-grade high school students tend to have a more systemic, broad understanding, while 7th-grade junior high school students focus more on concrete, practical, and individual matters. The differences found at both levels may be caused by different student cognitive development. Junior high school students who are still at the concrete-operational thinking stage tend to describe pollution visually and concretely, while high school students who have reached the formal-operational thinking stage begin to connect various aspects of pollution to cause-and-effect and systemic processes. In terms of conceptual understanding, junior high school students must be accustomed to working on problems that require them to analyze according to their abilities (Sutrisna, 2021). Junior high school students have several different concepts of environmental pollution. This is because junior high school students memorize material but do not understand the concepts they memorize (Ulfa et al., 2017). High school students often connect environmental pollution with global issues, whereas junior high school students remain in the context of textbooks and everyday life. In fact, environmental pollution has become a global issue, impacting not only ecosystems but also social life, the economy, and human health (Sompotan & Sinaga, 2022; Utami et al., 2023).

In education, schools play a strategic role in fostering students' environmental awareness and care (Alwasi et al., 2023; Kamil et al., 2019). Environmental pollution material incorporates scientific concepts and values of environmental care and responsibility. Through the material on environmental pollution, it is hoped that students will be able to recognize the causes, impacts, and solutions to pollution, connect it to global issues, and understand the definition of environmental pollution in its context. However, classroom learning is often theoretical, resulting in students' awareness of the importance of environmental protection being suboptimal and their understanding of the material being shallow. Teachers have stated that practical, contextual learning in the classroom is not possible due to time constraints. This is despite numerous cases of pollution occurring in the school environment, such as garbage in gutters and food stall waste, which should be used as case studies in learning. This is one of the reasons junior high school students understand environmental pollution only abstractly and fail to connect the subject matter to problems in their surroundings. Environmental pollution not only affects cognitive but also affective and social aspects, as it relates to ethical and moral values in learning, enabling students to better understand the importance of environmental protection and apply these values in their daily lives (Ariffiando et al., 2023). One solution to help students understand the concepts in each learning material is to find appropriate teaching methods (Purba, 2024).

Air and water pollution are dominant concepts among 10th-grade high school and 7th-grade junior high school students. Water is a basic human need. However, due to dense human activity, water becomes polluted and smells bad, leading to a decline in water quality. In Government

Regulation of the Republic of Indonesia No. 82 of 2001 concerning water quality management and water pollution control states that water pollution is the entry or introduction of living creatures, substances, energy and/or other components into water and/or changes in water systems due to human activities, so that water quality decreases to a certain level which causes the water to be unable to function according to its intended purpose.

A high school student in 10th grade mentioned the keyword "bacteria" in the definition of pollution. Bacteria, viruses, parasites, and toxic and hazardous chemicals can cause health problems and disrupt aquatic ecosystems (Kusuma, 2022). Efforts to control air pollution can be implemented through several approaches, such as technological development, environmentally conscious economic policies, law enforcement and regulations, and educational approaches (guidance, motivation, and public awareness are essential for participation in environmental sustainability). Some students also mentioned these efforts. Visual-based learning can facilitate students' conceptual understanding of environmental pollution. This is in line with research (Bogalecka & Grobelna, 2023), which explains that visual characteristics are easily remembered through visual association.

Students are not accustomed to analyzing existing problems and tend to prefer thinking without first analyzing the problem when presenting arguments (Dewina et al., 2017). In line with research conducted by Yulianti (Aseptianova et al., 2019), it is stated that understanding can help students organize their thoughts and determine better ways to solve a problem. Therefore, if students have a good understanding, the learning process will be easier to understand. The quality of education is greatly influenced by the level of understanding of each student. Student understanding is also influenced by external factors, such as education related to environmental pollution and environmental issues learned in school. Family factors can significantly influence students' knowledge and understanding, including social facilities, local culture, and the economy, which can form a positive correlation between understanding (Isenaj et al., 2024). Therefore, it is important for an individual to receive education at school to achieve a good quality of life, attitudes, and skills (Singh et al., 2023). Learning at school greatly influences the quality of students' thinking and actions. Teachers must be able to deliver material to students with appropriate learning methods. A student is said to have good perception if he can interpret the information received into an understanding that can be applied in daily activities (Safitri et al., 2020). When students are able to interpret the knowledge gained, students will be able to find solutions to problems that exist in their surroundings. A good learning environment and motivation can influence the results of high student perception (Prastiwi et al., 2019). In addition to schools, families and communities play a very important role in students' sensitivity and responsibility in finding solutions to a problem. In line with research conducted by Hafiar (Hafiar et al., 2019), it is said that student perception is getting higher because the quality of student learning is also high.

4. Conclusion

Based on the analysis of answers from tenth-grade high school students and seventh-grade junior high school students regarding environmental pollution, it is clear that the conceptual understanding of tenth-grade high school students is broader and more comprehensive than that of seventh-grade junior high school students, who are still partially and incompletely prepared. This is because the cognitive development of students at each age is different and learning strategies must be adjusted and improved. The results of the study prove that the higher the level of education, the more important concepts are discovered. The findings during the research process are very important for the world of education, especially in Natural Science (IPA) learning related to environmental issues. The results of the student data analysis prove that most tenth-grade high school students and seventh-grade junior high school students still have limited or inaccurate concepts in interpreting environmental pollution. This indicates the need for instilling more complete and meaningful concepts and the importance of learning strategies that not only emphasize the cognitive (knowledge) aspect, but also the affective (attitude) aspects of students. It

is hoped that students will be more motivated to demonstrate an attitude of care and responsibility towards the environment after understanding the meaning and impact of environmental pollution correctly. Learning should be directed not only at conveying concepts theoretically but also actively involving students through contextual methods, environmental projects, and value reflections so that students' attitudes towards protecting the environment can be firmly embedded. In addition, the development of visual-based learning media, such as word art and bar charts, can also be used to make it easier for students to understand and internalize the meaning of the concept of environmental pollution in a more interesting and in-depth way.

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