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# Multimodal Verbal Representations of Environmental Pollution: How Students Construct Meaning through Local Wisdom

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## ABSTRACT

Understanding environmental pollution and ecosystem degradation requires students not only to recognise environmental phenomena but also to articulate causal relationships through coherent scientific explanations. However, many students struggle to translate visual, graphical, and contextual information into structured verbal representations, limiting their ability to construct meaningful environmental concepts. While contextual and local wisdom–based learning has increasingly been promoted in science education, empirical evidence on how students develop verbal representations of environmental concepts within an ethnoecological framework remains limited. Addressing this gap, the present study investigates the initial profile of students' verbal representation skills in constructing knowledge of environmental pollution and damage through an ethnoecological learning perspective. A qualitative descriptive design was employed involving 20 tenth-grade students from SMAN 16 Surabaya selected through purposive sampling. Data were collected using a verbal representation test designed to measure three indicators: abstraction, relation, and extension across multiple representation types, including visual–verbal, verbal–verbal, graphic–verbal, and mathematical–verbal forms. The findings indicate that students demonstrate the highest achievement in abstraction through visual–verbal representation (100%) and relatively strong performance in verbal–verbal abstraction (84%), suggesting that visual scaffolding effectively supports conceptual explanation. Conversely, lower performance in graphic–verbal tasks indicates difficulties in interpreting data relationships and expressing them through systematic verbal reasoning. These results highlight the critical role of multimodal representation in facilitating conceptual construction within environmental learning contexts. This study contributes novel empirical insight into students' verbal representation profiles within ethnoecology-based environmental education and provides pedagogical implications for designing multimodal, context-responsive learning strategies that strengthen scientific communication and environmental literacy in secondary education.

## 1. Introduction

Understanding environmental challenges in the twenty first century requires students to move beyond memorising scientific facts toward interpreting complex environmental phenomena and communicating their understanding through clear and structured scientific explanations. This shift positions verbal representation as a central mechanism in learning, enabling students to transform observations, numerical data, and visual information into coherent conceptual knowledge. Language, therefore, functions not only as a communicative medium but also as a cognitive tool through which learners organise ideas, construct causal relationships, and express scientific reasoning within multimodal contexts (Tang et al., 2021; Padios et al., 2023; Palupi et al., 2019). Consequently, the development of scientific literacy is closely linked to students' ability to coordinate multiple representations through linguistically precise and genre aware explanations (Tang & Rappa, 2020; Tang, 2024; Afonso et al., 2019).

The growing emphasis on multimodality and language integration in science learning reflects broader educational priorities aligned with twenty first century competencies and global sustainability agendas. Learners are expected not only to understand scientific concepts but also to critically interpret, evaluate, and communicate knowledge within real world contexts. This orientation aligns with the demands of the Fourth Industrial Revolution and Society 5.0, where individuals are required to demonstrate critical awareness, problem solving skills, and ethical responsibility in addressing environmental and technological challenges (Hamzah et al., 2023). As a result, the integration of multimodal representation and verbal explanation becomes a fundamental component of meaningful participation in environmental discourse and decision making.

Environmental pollution and ecosystem degradation represent complex learning domains involving dynamic interactions among ecological systems, human behaviour, and policy frameworks. Understanding these issues requires students to interpret environmental evidence, analyse relationships among variables, and construct scientifically valid cause and effect explanations. However, empirical evidence consistently shows that many students experience difficulties in translating environmental observations and data into coherent explanations. Studies in the Indonesian context indicate that students' science literacy remains limited, particularly in their ability to analyse environmental phenomena and communicate evidence based reasoning (Nida et al., 2020; Dagamac & Darmawan, 2021; Lestari et al., 2023). These challenges reveal a gap between conceptual understanding and representational competence, highlighting the need for instructional approaches that explicitly support students in constructing and communicating environmental knowledge.

A growing body of research has explored the role of socioscientific issue based learning in enhancing environmental literacy and critical thinking. These approaches have been shown to support students' ability to evaluate environmental issues, engage in scientific communication, and develop responsible citizenship (Nida et al., 2021; Imamyartha et al., 2024; Dagamac & Darmawan, 2021). Despite these positive outcomes, their implementation remains inconsistent, often constrained by limited teacher expertise, challenges in curriculum alignment, and insufficient instructional resources (Nida et al., 2020; Nida et al., 2021; Dagamac & Darmawan, 2021). Moreover, existing studies tend to emphasise affective and attitudinal outcomes, while providing limited insight into the cognitive and representational processes through which students construct and articulate environmental knowledge. In particular, there remains a lack of empirical research examining how students translate multimodal information into structured verbal explanations, leaving a significant gap in the literature.

To address this gap, contextual learning approaches that integrate local ecological knowledge have gained increasing attention as effective strategies for enhancing environmental understanding. The incorporation of local wisdom allows students to connect scientific concepts with real environmental conditions in their communities, making learning more relevant and meaningful. In the context of Surabaya, mangrove ecosystems serve as a valuable ecological resource, functioning as natural protectors, pollution absorbers, and centres of community based conservation. These roles are supported by local environmental policies that promote sustainability practices (Agustina et al., 2023; Ivaningtias et al., 2024; Rafidah et al., 2024). However, prior studies have largely focused on the development of instructional materials and digital resources, with limited attention to how local wisdom contributes to students' representational and explanatory processes (Agustina et al., 2023; Ivaningtias et al., 2024; Rafidah et al., 2024). This study addresses this gap by positioning local wisdom as a cognitive resource that supports verbal representation and conceptual construction.

The present study is significant in that it bridges the domains of multimodal representation, verbal reasoning, and ethnoecological learning. It examines how students construct environmental knowledge through various representation forms, including visual verbal, verbal verbal, graphic verbal, and mathematical verbal modes. Previous research has established the importance of multiple representations in supporting conceptual understanding and higher order thinking (Ainsworth, 2006; Opfermann et al., 2017; Rosengrant et al., 2007; Damayanti and Kuswanto, 2021; Rahmawati and Anwar, 2020). Nevertheless, students often encounter difficulties when translating visual and graphical information into coherent verbal explanations, which can hinder meaningful learning (Huda et al., 2021). Accordingly, this study aims to explore students' verbal representation skills in constructing environmental concepts within an ethnoecological learning framework.

The findings of this study contribute to science education by providing empirical insights into how students construct environmental knowledge through verbal explanations supported by multiple representations. By identifying patterns in students' representational abilities, this research offers a basis for designing instructional strategies that address specific learning challenges, particularly in interpreting graphical data and articulating causal relationships within environmental systems. Strengthening these competencies is essential for improving students' conceptual understanding, scientific literacy, and ability to engage in environmental problem solving (Ainsworth, 2006; Damayanti and Kuswanto, 2021).

From an educational perspective, this study also has broader implications for interdisciplinary learning, particularly in contexts where language serves as a medium for academic communication. Environmental topics grounded in local wisdom provide authentic opportunities for students to develop explanatory, analytical, and argumentative skills while engaging with real world sustainability issues. Learning activities that require students to interpret multimodal information and construct evidence based explanations can simultaneously enhance language proficiency, scientific reasoning, and environmental awareness. Therefore, integrating multimodal environmental content into educational practice not only strengthens conceptual understanding but also supports the development of communicative competence and critical engagement in addressing contemporary environmental challenges.

## 2. Method

This study employed a mixed-methods research design to comprehensively examine students' verbal representation skills in constructing environmental concepts. The quantitative component was used to generate a structured profile of students' performance across representation indicators, while the qualitative component provided deeper insights into students' reasoning processes and interpretative strategies. This integration enabled a more robust understanding by combining measurable outcomes with explanatory depth, ensuring methodological complementarity and strengthening the validity of the findings.

The study focused on how students transform information from visual, textual, graphical, and numerical sources into structured verbal explanations. Specifically, it examined students' abilities to demonstrate abstraction, establish relationships among environmental variables, and extend conceptual understanding within an ethnoecological learning context.

### 2.1 Research Setting and Participants

The study was conducted from April to May 2025. Instrument development took place at the Postgraduate Programme in Biology Education, Universitas Negeri Surabaya, while data collection was carried out at State Senior High School 16 Surabaya. Participants consisted of twenty tenth grade students selected through purposive sampling. This approach ensured that participants had prior exposure to environmental topics and were capable of engaging meaningfully with multimodal representation tasks.

### 2.2 Research Instruments

Two instruments were used: a verbal representation test and semi-structured interviews. The verbal representation test assessed three indicators, namely abstraction, relation, and extension, across four representation types including visual verbal, verbal-verbal, graphic verbal, and mathematical verbal. The instrument consisted of ten items covering key environmental topics such as pollution, ecosystem damage, environmental policy, and mangrove-based phytoremediation. To complement this, semi-structured interviews were conducted to explore students' reasoning processes, interpretation strategies, and difficulties in translating multimodal information into verbal explanations. The interview protocol included open-ended questions that captured how students interpret data, organise explanations, and connect concepts with local ecological knowledge.

Content validity was ensured through expert review, and reliability was examined through consistency during the pilot testing stage. All items were designed based on higher order cognitive levels aligned with Bloom's taxonomy.

### 2.3 Data Collection

Data collection was conducted in two stages. First, students completed the verbal representation test individually, providing written explanations based on various representation formats. These responses formed the primary quantitative dataset. Second, selected students were interviewed based on variation in performance levels. This allowed for deeper exploration of students' cognitive processes and provided qualitative insights to support and explain the quantitative findings.

### 2.4 Data Analysis

Data analysis followed an integrated mixed-methods approach. Quantitative data were analysed descriptively using a coding rubric based on abstraction, relation, and extension indicators. The results were summarised using proportions to generate a performance profile of students' verbal representation skills. Qualitative interview data were analysed thematically to identify patterns in students' reasoning, interpretative strategies, and representational challenges. Finally, both datasets were integrated through triangulation, allowing quantitative trends to be interpreted alongside qualitative insights. This approach enhanced the credibility, coherence, and analytical depth of the study, providing a comprehensive understanding of students' verbal representation skills in environmental learning contexts.

## 3. Results

The findings demonstrate that students' verbal representation skills remain uneven and highly dependent on representation format. Visual representations significantly enhance conceptual understanding, while graphical and evaluative tasks reveal substantial limitations in reasoning and explanation. These patterns indicate that students are more capable of constructing explanations when supported by concrete visual cues but encounter increasing difficulty as tasks require abstract interpretation and higher order reasoning.

Therefore, the results in this section are organised to examine students' performance across task types, representation indicators, and cognitive demands, while also integrating qualitative insights to provide a deeper understanding of students' reasoning processes.

### 3.1 Overall Profile of Students' Verbal Representation Skills

The results reveal a clear and systematic pattern in students' verbal representation abilities. Students demonstrate strong performance in tasks supported by visual representations, while performance declines significantly as tasks require higher levels of abstraction, relational reasoning, and conceptual extension. This pattern indicates that students' representational competence remains uneven and highly dependent on the format of information presented, with visual scaffolding functioning as a dominant support mechanism in constructing explanations. Figure 1 presents the distribution of students' performance across the ten test items.

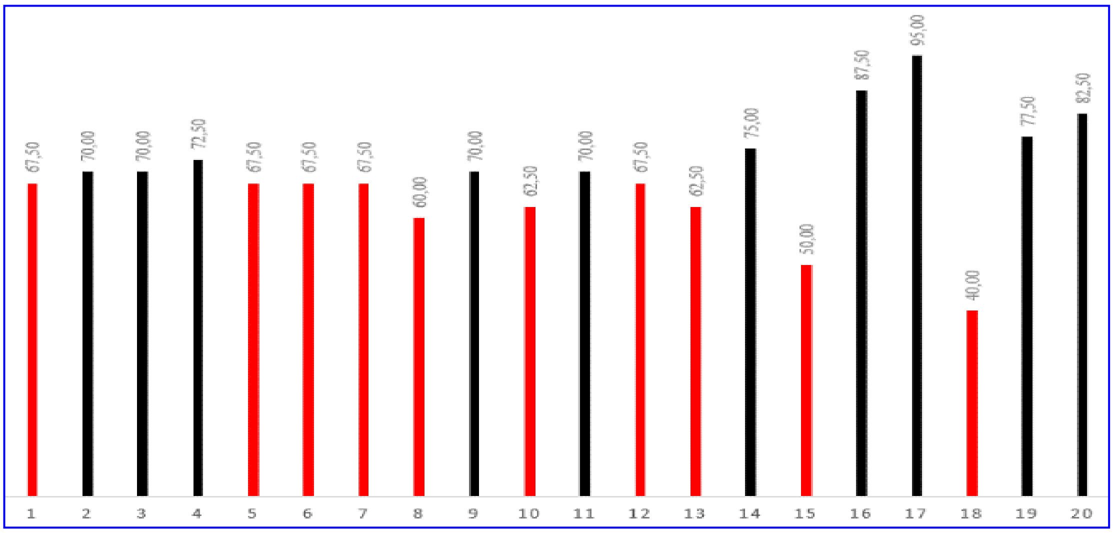


**Figure 1.** Students' Verbal Representation Test Performance Across Items

The results show that visually supported tasks achieve the highest completion rates, while tasks involving graphical interpretation and evaluative reasoning exhibit noticeably lower performance. This distribution confirms that representation format is a determining factor in students' ability to construct coherent verbal explanations. To provide structural clarity, Table 3.1 summarises the design of the assessment instrument.

**Table 3.1.** Structure of the Verbal Representation Test Instrument

| Question | Indicator | Representation Type | Cognitive Level | Concept |
|---|---|---|---|---|
| 1 | Relation | Verbal verbal | C4 | Pest management |
| 2 | Abstraction | Visual verbal | C4 | River pollution |
| 3 | Abstraction | Visual verbal | C4 | Mangrove phytoremediation |
| 4 | Relation | Verbal verbal | C4 | Soil degradation |
| 5 | Relation | Verbal verbal | C4 | Coastal damage |
| 6 | Extension | Verbal verbal | C5 | Environmental policy |
| 7 | Relation | Graphic verbal | C4 | Industrial pollution |
| 8 | Extension | Mathematical verbal | C5 | Urban pollution |
| 9 | Relation | Verbal verbal | C4 | Infrastructure impact |
| 10 | Relation | Verbal verbal | C4 | Mangrove damage |

The table indicates that most tasks are positioned at the analytical level, while several extend into evaluative reasoning, enabling a comprehensive assessment of students' performance across varying cognitive demands.

The high performance in visual verbal tasks reflects students' ability to rely on observable environmental cues when constructing explanations. Visual inputs appear to reduce cognitive complexity, allowing students to identify key elements and translate them into verbal descriptions with relative ease.

This tendency is reflected in students' responses:

*"Air sungainya kotor karena banyak sampah, jadi berbahaya untuk makhluk hidup di dalamnya."*
*"The river water is dirty because there is a lot of waste, so it is harmful for living organisms in it."*
(S07, Int-1, 12:34)

*"Banyak plastik di air menunjukkan pencemaran, jadi kualitas airnya menurun."*
*"There are many plastics in the water showing pollution, so the water quality decreases."*
(S12, Int-1, 18:02)

These responses demonstrate effective abstraction, where students successfully identify visible indicators of environmental problems and convert them into verbal explanations. However, the explanations remain descriptive, focusing primarily on surface-level features without elaborating underlying causal mechanisms.

As the task demands move beyond observation, students begin to show signs of difficulty in structuring explanations. This is evident in responses such as:

*"Pencemaran terjadi karena manusia, tapi saya bingung menjelaskan bagaimana prosesnya."*
*"Pollution happens because of humans, but I am confused about how to explain the process."*
(S03, Int-2, 27:15)

This response reflects partial conceptual understanding but reveals a breakdown in explanation. The student recognises causality but struggles to organise the reasoning into a coherent structure.

In some cases, students demonstrate emerging attempts to integrate knowledge and reasoning:

*"Mangrove bisa menyerap logam berat, jadi kalau mangrove banyak, pencemaran bisa berkurang dan lingkungan jadi lebih baik."*
*"Mangroves can absorb heavy metals, so if there are more mangroves, pollution can decrease and the environment becomes better."*
(S15, Int-2, 33:41)

The findings offer critical insight into students' representational competence. The challenge lies not only in understanding environmental concepts, but more importantly in transforming information across representational modes. Visual representations serve as effective cognitive entry points, helping students recognise and describe environmental phenomena. However, this support also fosters dependency, which constrains the development of independent analytical reasoning. At a deeper level, students' explanations remain largely descriptive, focusing on observable features rather than underlying causes, indicating that conceptual understanding has not yet been internalised into structured reasoning. When visual scaffolding is removed, students must rely on internal conceptual frameworks that appear underdeveloped, resulting in fragmented explanations.

Another key issue concerns the coordination of cognition and language. Constructing coherent explanations requires not only conceptual understanding but also the ability to organise ideas, establish relationships, and express them logically. Qualitative data indicate that students often hold partial understanding yet struggle to articulate it systematically, revealing a gap between conceptual knowledge and linguistic expression. At the same time, responses showing emerging integration suggest that students are not at a static level of understanding but in a transitional phase of representational development. They begin to connect concepts and recognise causal relationships, particularly in familiar contexts, but are not yet able to elaborate these connections into comprehensive explanations.

Overall, the findings reveal three interconnected conditions. First, students depend heavily on visual scaffolding to construct meaning. Second, they struggle to translate abstract information into structured verbal reasoning. Third, they demonstrate emerging integrative thinking, although this ability remains underdeveloped. These patterns indicate that the central challenge extends beyond conceptual understanding to the coordination of multimodal representation and language as an integrated process of meaning construction.

### 3.2 Performance Across Representation Indicators and Formats

Students demonstrate the highest achievement in abstraction, followed by moderate performance in relation, and the lowest performance in extension. This pattern reflects a progressive increase in difficulty as tasks require more complex reasoning, integration of information, and higher order thinking. It indicates that while students are able to identify and restate environmental concepts, they experience challenges when required to connect variables and extend reasoning into broader contexts.

**Table 3.2.** Summary of Representation Performance

| Indicator | Representation Forms | Performance Level |
|---|---|---|
| Abstraction | Visual verbal, verbal verbal | High |
| Relation | Verbal verbal, graphic verbal | Moderate |
| Extension | Verbal verbal, mathematical verbal | Moderate to Low |

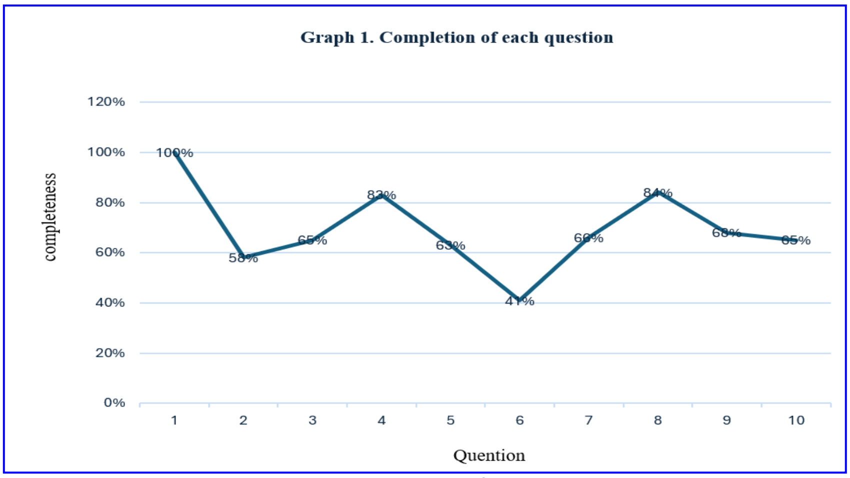


**Figure 2.** Completion Level for Each Test Item

The results indicate that abstraction tasks are completed more successfully than relation and extension tasks, particularly when supported by visual representations. In contrast, tasks requiring relational reasoning and conceptual extension show a clear decline in performance, highlighting the increasing cognitive demands associated with these indicators.

Students' strength in abstraction is evident in their ability to identify key concepts and restate them in simple terms. When tasks involve recognising information or describing observable phenomena, students are able to construct responses with relative confidence.

However, as tasks shift toward relational understanding, students begin to encounter noticeable difficulty. This is reflected in the following response:

*"Grafiknya menunjukkan pencemaran meningkat, tapi saya tidak tahu kenapa itu terjadi atau bagaimana menjelaskannya."*
*"The graph shows pollution is increasing, but I do not know why it happens or how to explain it."*
(S05, Int-2, 21:10)

This response illustrates a critical transition point in students' reasoning. While the student is able to recognise patterns within the data, they struggle to articulate the relationships between variables. The difficulty lies not in identifying information but in transforming that information into structured explanation.

A similar pattern is observed in other responses:

*"Ada hubungan antara jumlah industri dan pencemaran, tapi saya bingung menjelaskan kaitannya secara jelas."*
*"There is a relationship between the number of industries and pollution, but I am confused about how to explain the connection clearly."*
(S09, Int-2, 24:36)

This excerpt further highlights the gap between recognition and explanation. Students demonstrate awareness of relationships but lack the ability to organise their reasoning into coherent verbal form.

The challenge becomes more pronounced in extension tasks, where students are required to apply or evaluate concepts beyond the immediate context. For example:

*"Pemerintah harus membuat aturan untuk mengurangi pencemaran, tapi saya tidak tahu aturan seperti apa dan bagaimana cara kerjanya."*
*"The government should make rules to reduce pollution, but I do not know what kind of rules or how they work."*
(S02, Int-3, 31:08)

This response reflects a limitation in extending conceptual understanding into broader or more abstract contexts. Students are able to express general ideas but struggle to elaborate them into specific, reasoned arguments.

Further evidence of this limitation appears in the following response:

*"Populasi meningkat menyebabkan pencemaran, tapi saya tidak bisa menjelaskan prosesnya secara detail."*
*"Population growth causes pollution, but I cannot explain the process in detail."*
(S11, Int-3, 35:22)

Here, the student identifies a causal relationship but cannot develop the explanation further, indicating incomplete conceptual integration.

At the same time, there are indications of emerging representational integration in some responses:

*"Mangrove bisa menyerap polutan, jadi jika mangrove ditanam lebih banyak, pencemaran bisa berkurang dan ekosistem menjadi lebih stabil."*
*"Mangroves can absorb pollutants, so if more mangroves are planted, pollution can decrease and the ecosystem becomes more stable."*
(S15, Int-2, 33:41)

This response demonstrates an attempt to integrate ecological knowledge with causal reasoning. However, the explanation remains general and lacks analytical depth, suggesting that this ability is still developing.

The results reveal a clear progression in cognitive and representational complexity across the three indicators. Abstraction tasks primarily require identification and description, which students are able to perform effectively, especially when supported by visual cues. These tasks rely on recognition-based processing, where students can directly map observable features onto verbal expressions.

In contrast, relation tasks require students to move beyond recognition and engage in relational reasoning. This involves identifying connections between variables and explaining how these relationships operate. The qualitative data indicate that this transition introduces significant difficulty, as students struggle to organise and articulate relationships in a coherent manner. The challenge lies in coordinating conceptual understanding with linguistic expression.

Extension tasks present an even greater challenge, as they require evaluative and generative reasoning. Students must not only understand concepts but also apply them to new contexts, construct arguments, and justify their reasoning. The findings show that most students are not yet able to perform this level of reasoning effectively. Their responses tend to remain general, lacking specificity and depth.

A critical insight emerging from this analysis is that students' difficulties are rooted in the process of representational transformation. Moving from abstraction to relation and extension requires the integration of multiple cognitive processes, including interpretation, organisation, and articulation. Students are able to perform these processes in isolation but struggle to coordinate them simultaneously.

Furthermore, the data suggest that students' reasoning remains largely linear and surface-based. They tend to focus on single relationships rather than constructing interconnected explanations. This limits their ability to develop comprehensive understanding of environmental systems, which inherently involve complex interactions.

At the same time, the presence of partially developed responses indicates that students are not lacking conceptual awareness. Instead, they are in a stage of emerging representational competence, where they begin to recognise relationships and attempt integration, but lack the structural and linguistic tools to fully articulate their reasoning.

Overall, the findings indicate that students are in a transitional phase characterised by three key conditions. First, they demonstrate strong ability in identifying and describing concepts. Second, they experience difficulty in explaining relationships among variables. Third, they show limited capacity to extend reasoning into broader contexts. These patterns highlight that the core challenge lies in developing students' ability to coordinate multiple representations and transform them into structured, analytical explanations.

## 4. Discussion

A central finding of this study is that students demonstrate uneven development in verbal representation skills, with stronger performance in tasks supported by visual representations and weaker performance in tasks requiring graphical interpretation and conceptual extension. This pattern highlights the critical role of visual scaffolding in enabling students to organise environmental information and construct coherent explanations. When environmental phenomena are presented visually, students are better able to identify key elements and translate them into structured verbal reasoning, whereas tasks involving abstract data impose greater cognitive demands and often result in fragmented explanations. These findings reinforce the view that verbal representation is not merely a linguistic output but a complex cognitive process that integrates multiple forms of information into meaningful scientific explanations (Tang et al., 2021; Tang & Rappa, 2020; Padios et al., 2023).

The strong performance in visual verbal tasks further underscores the importance of multimodal scaffolding in supporting abstraction and conceptual reasoning. Visual representations function as cognitive anchors that make complex environmental processes more accessible, enabling students to identify relationships among variables and organise their ideas into coherent explanatory structures. Rather than serving as passive illustrations, these representations actively shape meaning construction by guiding attention and clarifying causal relationships. This finding aligns with studies demonstrating that multiple representations enhance higher order thinking and analytical reasoning in science learning contexts (Nooijen et al., 2024; Ng & Chan, 2020; Ibrahim & Damayanti, 2024). In addition, the theoretical framework of multiple representations emphasises that visual and symbolic forms complement each other in facilitating conceptual understanding (Ainsworth, 2006; Opfermann et al., 2017; Rosengrant et al., 2007).

From a cognitive perspective, the coordination of visual and verbal modes supports dual channel processing, allowing learners to distribute cognitive effort across visual and linguistic systems. This reduces cognitive load and enables more efficient knowledge construction, particularly when students engage with complex environmental information and relationships (Nooijen et al., 2024; Crum, 2021; Sherqobilovich, 2023). Importantly, learners actively construct meaning by selecting relevant information, interpreting patterns, and encoding these interpretations into verbal explanations. This active processing strengthens conceptual integration and supports deeper understanding, reinforcing evidence that representational competence is closely linked to conceptual mastery and reasoning development (Fatmawati et al., 2022; Wasis et al., 2023; Brata et al., 2023).

The effectiveness of multimodal scaffolding is further amplified when it is aligned with disciplinary discourse practices. When students interpret visual information through scientific language and genre conventions, they are more likely to produce explanations that are coherent, logically structured, and conceptually meaningful. This alignment enables learners to move from fragmented observations toward systematic explanations grounded in causal reasoning and scientific logic (Ng & Chan, 2020; Mendoza, 2023; Ibrahim & Damayanti, 2024). Furthermore, the ability to translate representations into structured verbal explanations is closely associated with students' capacity to engage in academic discourse and scientific communication (Rahmawati & Anwar, 2020; Septiani et al., 2020; Syifa et al., 2022).

In contrast, the lower performance observed in graphic verbal and verbal extension tasks reveals persistent challenges in representational coordination. These tasks require students to interpret abstract data, identify relationships among variables, and express these relationships through structured scientific language, processes that demand advanced cognitive and linguistic integration. Such difficulties are widely reported, particularly in students' struggles to translate graphical and mathematical representations into coherent verbal explanations (Huda et al., 2021; Fithrathy & Ariswan, 2019). Similarly, research on representation translation indicates that students often experience breakdowns when moving between symbolic, graphical, and verbal modes (Saputra et al., 2024; Takaoğlu, 2024; Rexigel et al., 2024). These findings highlight the need for explicit instructional support, including multimodal literacy development and language scaffolding, to enhance students' interpretative and explanatory abilities (Forey, 2020; Dios et al., 2020; Wang & Lin, 2025).

These findings extend existing literature by reinforcing the role of verbal representation as both a cognitive and communicative process in science learning. Students with stronger verbal representation skills tend to construct explanations that are coherent, logically structured, and conceptually complete, whereas those with weaker skills often produce fragmented responses. This pattern is consistent with studies demonstrating that verbal communication ability is closely linked to conceptual understanding and academic performance (Fatmawati et al., 2022; Amanda et al., 2024; Bal, 2015). In addition, the ability to articulate reasoning through language plays a crucial role in supporting higher order thinking and reflective learning processes (Putri et al., 2023; Damayanti & Kuswanto, 2021).

Another important implication concerns the role of instructional design in shaping representational competence. The findings indicate that verbal representation skills do not develop spontaneously but require structured scaffolding, explicit instruction, and continuous practice. Learning environments that integrate visual interpretation, graphical analysis, and structured explanation tasks can support students in developing more systematic and coherent reasoning. Previous studies highlight the effectiveness of scaffolding strategies, rubric based assessment, and iterative feedback in improving the quality of scientific explanations (Martin & Graulich, 2023; Yik et al., 2023; Crowder et al., 2024). Furthermore, project based and inquiry oriented approaches have been shown to enhance students' representational skills and critical thinking through active engagement with real world problems (Erman et al., 2022; Hoe et al., 2024; Widyawati et al., 2024).

A distinctive contribution of this study lies in its integration of ethnoecological learning as a contextual framework for developing verbal representation skills. By incorporating local wisdom, particularly through mangrove ecosystems, students are provided with authentic contexts that connect scientific concepts with real environmental practices. This contextualisation enables learners to construct explanations that are not only scientifically accurate but also grounded in lived experience. Previous research has shown that local wisdom based learning enhances environmental awareness and conceptual understanding (Agustina et al., 2023; Ivaningtias et al., 2024; Rafidah et al., 2024). In addition, the integration of indigenous and contextual knowledge has been shown to strengthen representational understanding and bridge the gap between abstract concepts and real world applications (Armanto et al., 2020; Karyati et al., 2024).

From a theoretical standpoint, the findings support and extend the framework of multiple representations in science education, which emphasises the complementary roles of different representation forms in facilitating conceptual understanding (Ainsworth, 1999; Ainsworth, 2006; Opfermann et al., 2017). Verbal representation serves as an integrative mechanism that enables students to synthesise information from visual, graphical, and contextual sources into coherent explanations. The variation in performance across representation types illustrates how representation format influences cognitive processing and reasoning, reinforcing the importance of representational competence in scientific learning (Kurnaz & Arslan, 2014; Wasis et al., 2023; Takaoğlu, 2024).

Despite these contributions, several gaps remain. The findings indicate that students continue to face difficulties in translating abstract representations into structured verbal explanations, particularly in tasks requiring higher order reasoning. This suggests that current instructional practices may not sufficiently support the development of representational coordination. The novelty of this study lies in its focus on verbal representation within an ethnoecological environmental learning context, which has received limited attention in previous research. By examining how students construct environmental knowledge through multimodal representations grounded in local wisdom, this study provides new insights into the intersection of cognitive, linguistic, and contextual dimensions of learning.

These findings carry important implications for science education and interdisciplinary learning. Instructional design should emphasise the integration of multiple representations, explicit language scaffolding, and contextual learning environments aligned with students' lived experiences. Integrating local ecological knowledge offers meaningful opportunities to engage with environmental issues while strengthening scientific reasoning and communication skills. These approaches are particularly relevant in educational contexts where language plays a central role in mediating conceptual understanding and supporting scientific discourse (Putri et al., 2023; Damayanti & Kuswanto, 2021).

Future research should focus on developing instructional interventions that explicitly target verbal representation skills within multimodal learning environments. Longitudinal studies involving larger and more diverse populations are needed to examine how representational competence evolves over time and across different contexts. Further research is also required to explore the integration of environmental learning with language education, particularly in English as a foreign language settings where students must communicate scientific ideas through academic discourse. In addition, future studies may investigate the effectiveness of innovative pedagogical approaches, including inquiry based learning, project based learning, and digital multimodal tools, in enhancing students' ability to translate complex environmental information into coherent explanations. Such research has the potential to advance both environmental education and language learning by fostering students' capacity to think critically, communicate effectively, and engage meaningfully with global sustainability challenges.

## 5. Conclusions

This study investigated students' verbal representation skills in constructing concepts related to environmental pollution and environmental damage within an ethnoecological learning context. The findings reveal that students' verbal representation abilities are still developing and vary according to the representation format involved in the learning task. Students demonstrated stronger performance in abstraction tasks supported by visual representations, while lower performance was observed in tasks that required interpreting graphical data or extending explanations to broader environmental contexts. These results indicate that visual information plays an important role in helping students organise environmental knowledge and articulate conceptual explanations.

From a theoretical perspective, the study contributes empirical evidence to the framework of multiple representations in science learning by demonstrating how visual, verbal, graphical, and mathematical representations influence students' conceptual reasoning. The findings highlight that verbal representation functions not only as a communication skill but also as a cognitive process through which learners integrate information from different representations and construct meaningful explanations. In addition, the integration of local wisdom through an ethnoecological learning approach shows that contextual environmental knowledge can serve as a powerful resource for strengthening conceptual understanding and connecting scientific ideas with real ecological practices.

The pedagogical implications of this study emphasise the importance of designing learning environments that explicitly train students to translate information across multiple representation formats. Instruction that integrates visual representations, graphical interpretation, and structured explanation tasks can help students develop stronger representational coordination and scientific reasoning. Environmental learning that incorporates local ecological knowledge also provides meaningful contexts that enhance students' engagement, environmental awareness, and conceptual understanding.

Despite these contributions, the findings should be interpreted within the scope of the study's limitations. The research involved a relatively small group of participants and relied on a single measurement of students' verbal representation abilities. Future research should therefore examine larger and more diverse student populations and explore how verbal representation skills develop through sustained instructional interventions. Further studies may also investigate how multimodal environmental learning can be integrated into interdisciplinary contexts, particularly in English language teaching environments where students are required to communicate scientific concepts through academic language. Such research has the potential to advance both environmental education and language learning by promoting students' ability to interpret complex information and express scientific ideas effectively.

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