ASEAN Journal for Science Education

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajsed

Enhancing Students' Conceptual Understanding and Sustainability Awareness through Fishbone-Oriented Instruction in Science Learning to Support Sustainable Development Goals (SDGs)

Wafa P. Cali, Hannah P. Abdulmalik*

Mindanao State University, Philippines

*Correspondence: E-mail: wafa.cali@msumain.edu.ph

ABSTRACT

This study examines the effectiveness of Fishbone-Oriented Instruction in enhancing students' conceptual understanding and sustainability awareness in science learning. Using a mixed-method approach with a one-group pretest–posttest design, the study involved secondary school students. Quantitative data from a conceptual understanding test were analyzed using normalized gain scores, while qualitative data were obtained through observations, reflective journals, and interviews. The results show a moderate improvement in students' conceptual understanding, particularly in identifying causal relationships and explaining scientific phenomena. Qualitative findings indicate that Fishbone-Oriented Instruction promotes active participation, structured reasoning, and collaborative discussion, enabling students to connect scientific concepts with real-world sustainability issues. Overall, the findings suggest that Fishbone-Oriented Instruction is an effective pedagogical strategy for supporting conceptual learning and sustainability-oriented thinking in science education.

© 2026 Bumi Publikasi Nusantara

ARTICLE INFO

Article History:

Submitted/Received 17 Oct 2025
First Revised 16 Nov 2025
Accepted 19 Jan 2026
First Available online 20 Jan 2026
Publication Date 01 Sep 2026

Keyword:

Conceptual understanding,
Fishbone diagram,
Fishbone oriented instruction,
Science.

1. INTRODUCTION

Conceptual understanding is a fundamental goal of science education, as it enables students to explain scientific phenomena, identify causal relationships, and apply knowledge meaningfully to real-world contexts. However, many studies have reported that science learning in secondary schools often emphasizes factual recall and procedural problem solving rather than deep conceptual reasoning, resulting in fragmented understanding and limited transfer of knowledge (Chi, 2009). This challenge is particularly evident when students are required to analyze complex problems involving multiple causes and consequences, such as those related to environmental and sustainability issues.

In recent years, science education has increasingly highlighted the importance of instructional approaches that support higher-order thinking, structured reasoning, and active student engagement. Approaches that encourage students to analyze problems systematically and visualize causal relationships have been shown to improve conceptual understanding and scientific reasoning skills (Hmelo-Silver *et al.*, 2007). At the same time, integrating sustainability issues into science learning has become a global priority, aligned with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 12 (Responsible Consumption and Production). Science classrooms are expected not only to develop conceptual knowledge but also to foster students' awareness of sustainability challenges and their ability to analyze socio-environmental problems critically.

Fishbone-Oriented Instruction (FOI) offers a pedagogical framework that emphasizes structured problem analysis through the identification of causes and effects using visual representations. Originally derived from the fishbone diagram, this approach has been adapted for educational contexts to support students in organizing ideas, examining relationships among variables, and constructing coherent explanations (Dogru, 2008). Previous research suggests that visual and cause–and–effect–based instructional strategies can enhance students' conceptual understanding by making abstract relationships more explicit and cognitively accessible (Ainsworth, 2006). Nevertheless, empirical evidence on the effectiveness of Fishbone-Oriented Instruction in science learning, particularly in relation to sustainability awareness, remains limited.

Existing studies on science instruction have largely focused on inquiry-based learning, problem-based learning, and concept mapping to promote conceptual change and reasoning skills (Hmelo-Silver *et al.*, 2007; Chi, 2009). Comparatively fewer studies have examined fishbone-based instructional approaches as a structured reasoning tool in science classrooms. Moreover, the integration of FOI with sustainability-oriented content has not been sufficiently explored, leaving a gap in understanding how this instructional approach may simultaneously support conceptual learning and students' awareness of sustainable development issues.

Addressing this gap, the present study investigates the effectiveness of Fishbone-Oriented Instruction in enhancing students' conceptual understanding and sustainability awareness in science learning. Specifically, the study aims to examine changes in students' conceptual understanding before and after the implementation of FOI and to explore students' learning experiences during the instructional process. By integrating structured reasoning with sustainability-oriented science content, this study contributes to the development of pedagogical strategies that support meaningful learning and align science education with global sustainability goals.

2. METHOD

This study employed a mixed-method approach using a one-group pretest–posttest design to examine the effectiveness of FOI in enhancing students' conceptual understanding and sustainability awareness in science learning. The quantitative component was used to measure changes in students' conceptual understanding before and after the instructional intervention, while the qualitative component aimed to capture students' learning experiences and perceptions during the implementation of FOI. This approach allowed the study to integrate learning outcome data with descriptive classroom insights, providing a comprehensive view of the instructional impact.

The participants were secondary school students enrolled in a science course, and the intervention was conducted during regular classroom sessions as part of the existing curriculum. All participants received the same instructional treatment, and no control group was involved. Before the intervention, students had limited experience with structured problem-analysis strategies using visual representations such as fishbone diagrams. Participation in the study was voluntary, and students were informed about the purpose of the research.

The instructional procedure began with the administration of a pretest to assess students' initial conceptual understanding. During the learning process, Fishbone-Oriented Instruction was implemented over several instructional sessions. Students were introduced to the fishbone diagram as a visual tool to analyze scientific problems by identifying central issues and organizing possible causes into related categories. Guided by the teacher, students worked individually and in small groups to construct fishbone diagrams based on science topics related to sustainability issues. The learning activities emphasized identifying cause–and–effect relationships, discussing alternative explanations, and connecting scientific concepts to real-world contexts. At the end of the instructional sequence, a posttest was administered to measure changes in students' conceptual understanding.

Quantitative data were collected using a conceptual understanding test designed to assess students' ability to explain scientific concepts, identify causal relationships, and apply knowledge to problem situations. The test items were reviewed to ensure content validity, and the reliability of the instrument was examined using internal consistency analysis. Qualitative data were obtained through classroom observations, students' reflective journals, and semi-structured interviews. Observations focused on student engagement and interaction during FOI activities, while reflective journals and interviews provided insights into students' reasoning processes and perceptions of the instructional approach.

Quantitative data from the pretest and posttest were analyzed using normalized gain (N-gain) scores to determine the level of improvement in students' conceptual understanding. The gain scores were interpreted using established criteria to categorize learning improvement levels. Qualitative data were analyzed thematically by identifying recurring patterns related to students' engagement, reasoning, and learning experiences. The integration of quantitative and qualitative findings was used to strengthen the interpretation of the results.

Ethical considerations were addressed by informing participants about the study objectives and ensuring the confidentiality of student responses. The instructional activities were conducted as part of normal classroom practice and did not interfere with students' academic evaluation.

3. METHOD RESULTS AND DISCUSSION

3.1. Normalized Gain of Students' Conceptual Understanding After the Intervention

This section reports and discusses the quantitative results of students' conceptual understanding after the implementation of FOI, supported by qualitative evidence that explains the observed learning gains. Students' conceptual understanding was measured using a researcher-developed Conceptual Understanding Test, and learning improvement was analyzed through normalized gain (N-gain) following the classification proposed by Hake (1998). The analysis involved two intact Grade 9 sections, namely Nuh and Yunos, to determine the extent to which FOI facilitated meaningful conceptual improvement in science learning. Students' normalized gains across the two sections are summarized in **Table 1**, which presents the distribution of learners according to low, medium, and high gain categories, along with the average and overall normalized gain after the intervention.

Table 1. Normalized gain, average gain, overall normalized gain, and interpretation of students' conceptual understanding in science after intervention.

Sections	Low gain	Medium gain	High gain	Ave. Gain	Overall N-gain	Interpretation
Nuh	0	31	6	0.61		Medium gain
Yunos	0	20	11	0.64	**0.62**	Medium gain
Total	**0**	**51**	**17**			**Medium gain**

Note. Normalized gain (g): g > 0.70 = high gain; 0.30 < g < 0.70 = medium gain; g < 0.30 = low gain. Adapted from Hake (1998).

As shown in **Table 1**, both sections achieved medium normalized gains, with Section Nuh obtaining an average N-gain of 0.61 and Section Yunos achieving a slightly higher average N-gain of 0.64. When combined, the two sections produced an overall normalized gain of 0.62, which is categorized as medium gain based on Hake's (1998) criteria. Importantly, no student from either section fell into the low-gain category, indicating that all participants experienced measurable conceptual improvement following the FOI intervention.

A medium normalized gain indicates that students were able to achieve a substantial proportion of the maximum possible learning improvement (Hake, 1998). In this study, the overall gain suggests that Fishbone-Oriented Instruction effectively supported students in developing conceptual understanding by enabling them to reorganize prior knowledge, address misconceptions, and construct clearer cause-and-effect relationships in science topics. The presence of several students in the high-gain category, particularly in Section Yunos, further indicates that FOI may be especially effective for learners who benefit from structured, visual, and inquiry-oriented learning environments.

The absence of low-gain outcomes is a particularly noteworthy result. This finding suggests that FOI helped prevent learning stagnation among lower-performing students by providing scaffolding through visual organization and guided analysis. Such outcomes are consistent with previous studies reporting that visual mapping and fishbone-based instructional strategies promote inclusive learning by supporting learners with varying cognitive abilities (Suryani & Hendri, 2019; Hidayat & Rohman, 2019). By decomposing complex scientific phenomena into identifiable causes and effects, students were guided toward deeper conceptual processing rather than surface-level memorization.

From a theoretical standpoint, the observed learning gains align with the principles of interactive engagement, which emphasize that students achieve higher learning gains when they actively construct knowledge through participation, discussion, and problem-solving activities (Hake, 1998). Fishbone-Oriented Instruction requires learners to collaborate, reason analytically, and visually represent relationships among concepts, all of which contribute to higher cognitive engagement. This approach also corresponds with sociocultural theory, which highlights learning as a socially mediated process where understanding is co-constructed through interaction and guided support.

The quantitative findings presented in **Table 1** are further supported by qualitative evidence obtained from post-intervention student interviews. Students consistently described positive learning experiences associated with FOI, including improved understanding of science concepts, enhanced collaboration, and increased confidence in completing academic tasks. These perceptions help explain why students demonstrated measurable improvements in their posttest performance.

For instance, several students reported that the use of fishbone diagrams helped them understand lessons more clearly and connect ideas logically. Others emphasized that the strategy encouraged group collaboration and idea sharing, which contributed to a more engaging learning environment. Such responses suggest that the gains observed in the normalized gain analysis were not the result of test familiarity alone but reflected genuine conceptual development, supported by meaningful learning processes (Latha & Prasad, 2019; Patel & Pradhan, 2018).

One student expressed positive emotions toward the strategy, stating:

EGP8: "I'm happy because we have this technique of teaching that enables us to work together as a group to share our thoughts and ideas."

This response indicates that FOI fostered collaborative learning and idea sharing, which are essential components of meaningful learning experiences in constructivist classrooms. Another student highlighted the role of FOI in improving conceptual recall:

EGP44: "First of all, nakakatuwa po meron ganitong uri na pagtuturo kasi nakakatulong ito para maalala namin ang mga key concepts ng aming pinag-aaralan."

(I'm happy that there is this kind of teaching because it helps us remember the key concepts of what we are studying.)

This statement suggests that the visual and structured nature of the fishbone diagram supported memory and understanding by organizing information in a meaningful way, consistent with findings on visual learning strategies in science education (Wang *et al*., 2018).

Students also reported that FOI enhanced their analytical skills and confidence in academic tasks. One participant explained:

EGP52: *"Ok po ako sa ganitong uri ng pagtuturo na gumamit ng fishbone diagram kasi na-iidentify ko ang mga causes and sub-causes sa isang main issue."*

(I'm okay with this kind of teaching that uses a fishbone diagram because I can identify the causes and sub-causes of a main issue.)

Similarly, another student emphasized improved understanding and conceptual connection:

EGP67: *"Happy because I understand the lesson better, po in the use of the fishbone diagram. I can connect the ideas."*

These interview excerpts demonstrate that students were not merely memorizing information but were actively analyzing relationships and constructing conceptual connections. Such higher-order thinking processes directly explain the medium-to-high normalized gains observed after the intervention and support the effectiveness of FOI as an interactive and analytical instructional approach (Patel & Pradhan, 2018; Latha & Prasad, 2019).

To further explain how FOI supported students' conceptual understanding, students' journal entries were examined. As shown in **Figure 1**, one student demonstrated an accurate understanding of how Earth's movement and axial tilt influence the seasonal appearance of constellations, explicitly attributing this understanding to the use of a fishbone diagram. Similarly, another student's journal entry illustrated how the fishbone diagram was used to analyze environmental problems by identifying a main issue and systematically breaking it down into causes and effects. This is evident in **Figure 2**, where the student analyzed pollution by identifying contributing factors and resulting consequences.

2. How did the fishbone diagram help you organize or connect ideas during the lesson?

It helped me organize my answer by showing that constellations change with the seasons because of earth's movement and tilt. The fishbone diagram helped me connect all these ideas and understand the concept better.

EGP66: *It helped me organize my answer by showing that constellations change with the seasons because of earth's movement and tilt. The fishbone diagram helped me connect all these ideas and understand the concept better.* (It helped me organize my answer by showing that constellations change with the seasons because of the Earth's movement and tilt. The fishbone diagram also helped me connect these ideas and understand the concept better.)

Figure 1. Journal entry of EGP66 dated October 15, 2025.

1. What are the key concept you have learned after using the fishbone diagram?

-> I learned how to identify the main problems or topic and break it down into its causes effect
-> Example : In Science if the main problem is "pollution" the diagram helped me see the causes like smoke, plastic and waste, and the effect like climate change

EGP37: *I learned how to identify the main problems and break down into causes effect. For example: In Science if the main problems is pollution. The diagram helped me see the causes like smoke, plastic, and waste and the effect like climate change.* (I learned how to identify the main problem and break it down into its causes and effects. For example, in Science, if the main problem is pollution, the diagram helped me see the causes such as smoke, plastic, and waste, as well as the effects such as climate change.)

Figure 2. Journal entry of EGP37 dated October 6, 2025.

These journal entries indicate that students were able to articulate scientifically accurate explanations while demonstrating causal reasoning and conceptual linkage. Such abilities are strong indicators of improved conceptual understanding and help explain the medium-to-high normalized gains reported in the quantitative results. The use of visual frameworks allowed students to transform abstract concepts into structured representations that supported analysis and explanation, consistent with findings from prior research on visual learning strategies in science education (Chang *et al*., 2019; Wang *et al*., 2018).

The convergence of quantitative and qualitative findings strengthens the validity of the results through methodological triangulation. Students' explanations in journal entries and interviews reveal that FOI encouraged learners to move beyond rote memorization toward analytical and reflective thinking. This outcome aligns with constructivist learning theory, which emphasizes that learners develop a deeper understanding when they actively organize and interpret information through meaningful activities.

Overall, the findings in this subsection demonstrate that Fishbone-Oriented Instruction effectively enhanced students' conceptual understanding in science, as evidenced by medium normalized gains and supported by rich qualitative data. By integrating visual organization, collaborative inquiry, and analytical reasoning, FOI created learning conditions that facilitated meaningful conceptual change, consistent with both empirical research and established theoretical frameworks (Suryani & Hendri, 2019).

The qualitative interview data are further reinforced by students' reflections regarding their sense of responsibility and confidence during learning activities. One participant highlighted how Fishbone-Oriented Instruction encouraged accountability and confidence in presenting group outputs:

EGP30: *"I felt okay po sa way of teaching na ito kasi para na oblige po kami na gawin ang aming assignment at nagkaroon kami ng confidence na i-present ang aming output."*

(I felt okay with this kind of teaching because we were obliged to do our assignment and gained confidence in presenting our output.)

This response indicates that FOI not only enhances students' conceptual understanding but also fosters positive learning behaviors such as responsibility, confidence, and willingness to participate. These affective outcomes are closely linked to cognitive engagement, as students who feel confident and responsible are more likely to invest effort in understanding learning materials deeply.

The role of Fishbone-Oriented Instruction in helping students analyze cause-and-effect relationships was also repeatedly emphasized during the interviews. For instance, one student explicitly explained how the strategy enabled them to identify causal structures within scientific problems:

EGP52: *"Ok po ako sa ganitong uri ng pagtuturo na gumamit ng fishbone diagram kasi na-iidentify namin ang mga causes/categories and sub-causes and sub-categories sa isang main issue or problem."*

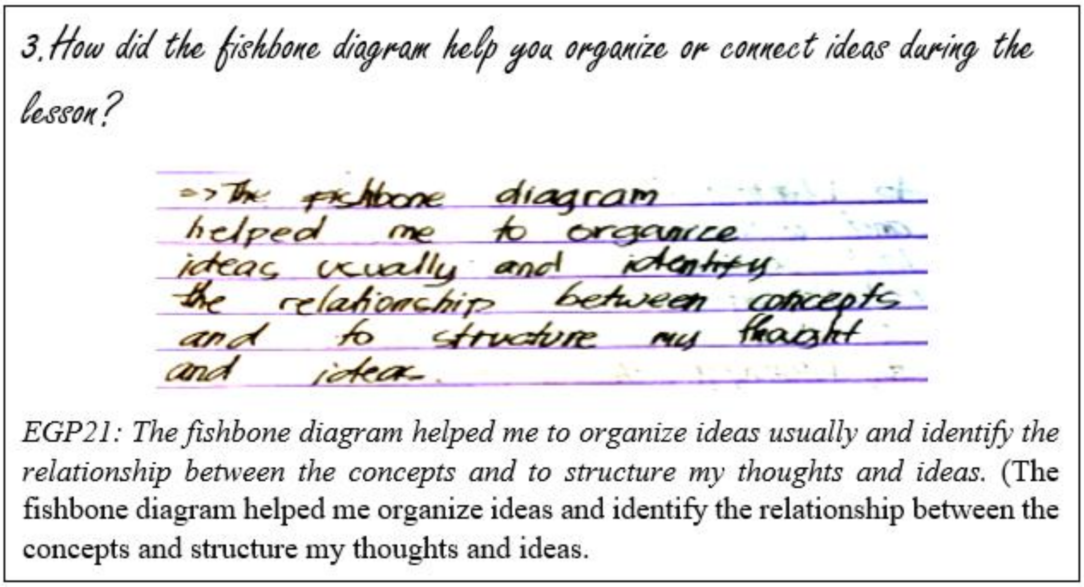
Similarly, another participant described how the fishbone diagram visually connected multiple causes to a central scientific issue:

EGP30: *"Sa pamamagitan ng diagram, pinapakita ang mga causes ay konektado sa main problem or issue, for example biodiversity."*

(Through the diagram, the causes are shown to be connected to the main problem or issue, such as biodiversity.)

These statements demonstrate that FOI supported students in developing analytical reasoning by explicitly guiding them to categorize, relate, and evaluate causal factors within scientific phenomena. Such skills are central to conceptual understanding in science, where learners must move beyond identifying isolated facts toward recognizing relationships and systems (Driver *et al*., 2000).

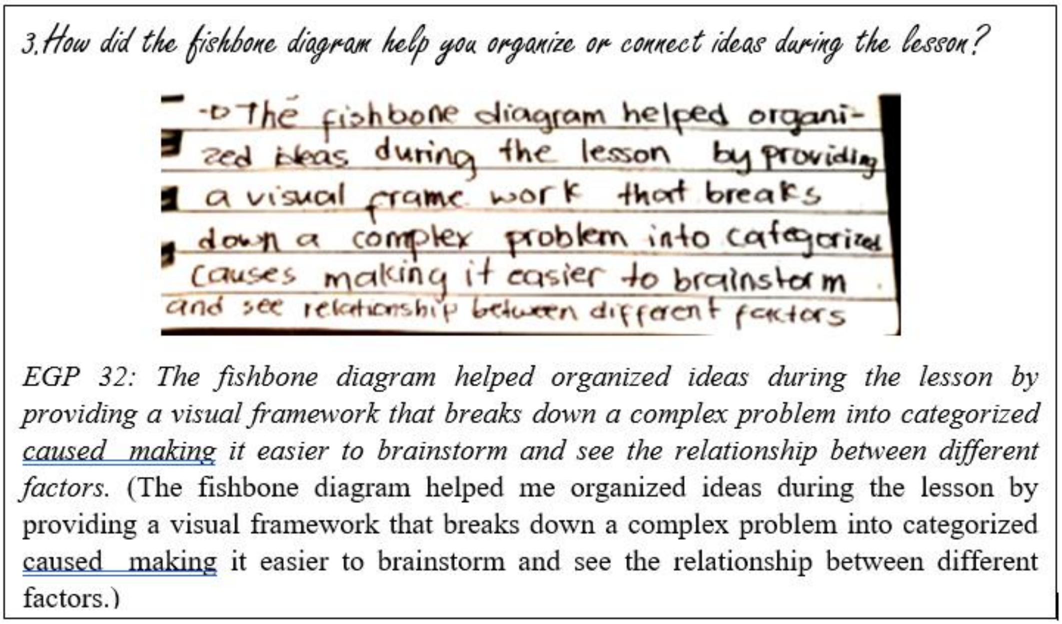
To further substantiate the interview findings, additional journal entries were examined. As shown in **Figure 3**, one student described how the fishbone diagram helped organize ideas and clarify relationships among scientific concepts, enabling more structured thinking during the lesson. Similarly, **Figure 4** illustrates another student's reflection on how the fishbone diagram provided a visual framework that broke down complex problems into categorized causes, making it easier to brainstorm and identify relationships among variables.


3. How did the fishbone diagram help you organize or connect ideas during the lesson?

=> The fishbone diagram helped me to organize ideas usually and identify the relationship between concepts and to structure my thaught and ideas.

EGP21: The fishbone diagram helped me to organize ideas usually and identify the relationship between the concepts and to structure my thoughts and ideas. (The fishbone diagram helped me organize ideas and identify the relationship between the concepts and structure my thoughts and ideas.

Figure 3. Journal entry of EGP21 dated September 3, 2025.


3. How did the fishbone diagram help you organize or connect ideas during the lesson?

-> The fishbone diagram helped organi-zed ideas during the lesson by providing a visual frame work that breaks down a complex problem into categorized causes making it easier to brainstorm and see relationship between different factors

EGP 32: The fishbone diagram helped organized ideas during the lesson by providing a visual framework that breaks down a complex problem into categorized caused making it easier to brainstorm and see the relationship between different factors. (The fishbone diagram helped me organized ideas during the lesson by providing a visual framework that breaks down a complex problem into categorized caused making it easier to brainstorm and see the relationship between different factors.)

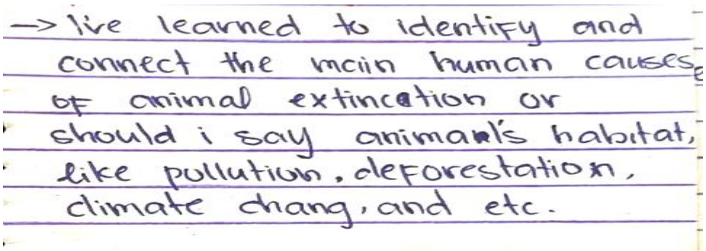
Figure 4. Journal entry of EGP32 dated September 17, 2025.

These journal entries indicate that Fishbone-Oriented Instruction supported students' cognitive organization processes by providing a clear visual structure for analyzing scientific information. Visual frameworks such as fishbone diagrams allow learners to externalize their thinking, reduce cognitive load, and integrate new information with prior knowledge, which are key mechanisms underlying conceptual change (Wang *et al*., 2018; Chang *et al*., 2019).

Beyond organizing ideas, students also demonstrated an increased ability to connect classroom learning with real-world environmental issues. As illustrated in **Figure 5**, one student identified human activities such as pollution, deforestation, and climate change as root causes of biodiversity loss, reflecting an understanding of anthropogenic impacts on the environment.

In a similar manner, **Figure 6** shows a student's reflection on how biodiversity is affected by deforestation, pollution, and climate change, explicitly linking human actions to ecological consequences such as habitat loss and species reduction.

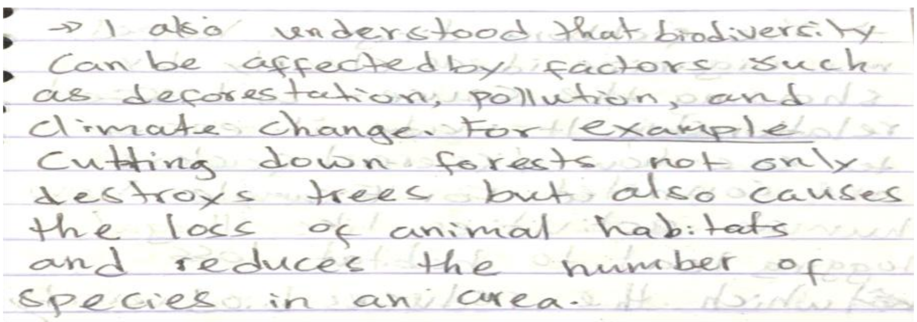
2. *How do the fishbone diagram help your organize or connect ideas during the lesson?*


→ I've learned to identify and connect the mcin human causes of animal extincation or should i say animal's habitat, like pollution, deforestation, climate chang, and etc.

EGP43: *I have learned to identify and connect the main human causes of animal extinction, or should I say animals' habitat, like pollution, deforestation, climate change, etc.* (I have learned to identify and connect the main human causes of animal extinction which are pollution, deforestation, climate change, and etc.)

Figure 5. Journal entry of EGP43 dated September 3, 2025.

3. *How do the fishbone diagram help your organize or connect ideas during the lesson?*


→ I also understood that biodiversity can be affected by factors such as deforestation, pollution, and climate change. For example Cutting down forests not only destroys trees but also causes the loss of animal habitats and reduces the number of species in an area.

EGP 24: I also understood that biodiversity can be affected by factors such as deforestation, pollution, and climate change. For example, cutting down forests not only destroys trees but also causes the loss of animal habitats and reduces the number of species in an area. (I also learned that biodiversity can be affected by factors such as deforestation, pollution, and climate change. For example, cutting down forests not only destroys trees but also leads to the loss of animal habitats and a decrease in the number of species in an area.)

Figure 6. Journal entry of EGP24 dated September 3, 2025.

These reflections indicate that students were able to apply scientific concepts to real-life contexts, a key indicator of deep conceptual understanding. The ability to link abstract scientific ideas to authentic environmental problems suggests that FOI facilitated meaningful learning experiences aligned with the goals of science education and sustainable development (Soren *et al*., 2023).

From a theoretical perspective, these findings align with constructivist learning theory, which emphasizes that learners actively construct knowledge by integrating new information with existing cognitive structures through meaningful activities. By engaging students in analyzing real-world problems using fishbone diagrams, FOI created opportunities for learners to reflect, discuss, and reconstruct their understanding collaboratively.

Furthermore, the emphasis on identifying human-induced environmental problems reflects the relevance of FOI in supporting education for sustainable development. As students analyzed issues such as pollution, deforestation, and climate change, they demonstrated increased awareness of human responsibility and environmental consequences, which are central themes in science education aligned with Sustainable Development Goals (see https://doi.org/10.1787/5f07c754-en). This suggests that FOI not only improved conceptual understanding but also supported the development of environmental awareness and responsible thinking among learners.

The convergence of interview data, journal entries, and quantitative gains strengthens the credibility of the findings through methodological triangulation. Students' consistent reports of improved understanding, analytical reasoning, and engagement provide strong explanatory support for the medium normalized gains observed in the posttest results. These outcomes mirror findings from previous studies indicating that fishbone diagrams enhance students' ability to analyze causal relationships, organize ideas, and engage actively in science learning (Suryani & Hendri, 2019; Patel & Pradhan, 2018).

Overall, the results presented in this subsection demonstrate that Fishbone-Oriented Instruction effectively facilitated conceptual understanding by integrating visual organization, analytical reasoning, and real-world application. The medium-to-high normalized gains observed across both sections are best understood as the outcome of these interconnected learning processes rather than as isolated quantitative improvements. As such, FOI emerges as a powerful instructional approach that supports both cognitive and affective dimensions of science learning.

This discussion of normalized gain and supporting qualitative evidence provides a strong foundation for the next subsection, which examines students' perceptions of Fishbone-Oriented Instruction as a learning strategy in science. The following subsection further explores how students experienced FOI in terms of visual structuring, cause-and-effect understanding, engagement, collaboration, and idea expression, building upon the learning outcomes discussed in this section.

3.2. Students' Perceptions of Fishbone-Oriented Instruction as a Learning Strategy in Science

This subsection discusses students' perceptions of FOI as a learning strategy in science, drawing from qualitative data obtained through student journal entries, individual interviews, and the researcher's field notes. While the above subsection focused on how FOI contributed to measurable gains in conceptual understanding, this subsection emphasizes how students experienced the learning process itself, particularly in terms of visual organization, causal reasoning, engagement, collaboration, and idea expression. Through thematic analysis, four interrelated themes emerged, as summarized in **Table 2**.

Table 2. Generated key themes based on students' perceptions of fishbone-oriented instruction.

Codes	Themes
Identifying root causes of problems; Understanding relationships among causes; Human activities as causes (e.g., pollution, deforestation, climate change); Concept of anthropogenic causes	Visual Structuring and Connection of Ideas
Organization of ideas; Visual learning/mapping; Categorization/grouping of causes; Clarity and structure in thinking; Problem-solving and identifying patterns	Understanding Cause-and-Effect Relationships
Increased engagement and interest; Hands-on learning; Participatory learning; Collaboration	Enhanced Engagement, Interest, Collaboration, and Participation
Sharing and contributing ideas; Brainstorming; Role-switching; Reflective learning	Valuing Idea Sharing and Student Expression

As shown in **Table 2**, students perceived Fishbone-Oriented Instruction positively across multiple dimensions of learning. The themes suggest that FOI functioned not only as a visual aid but as a comprehensive pedagogical strategy that integrated cognitive organization, social interaction, and affective engagement. These findings align with previous research showing that fishbone diagrams support analytical thinking, conceptual clarity, and student engagement in science learning (Clary & Wandersee, 2010; Istikomah, 2017).

3.3. Visual Structuring and Connection of Ideas

One of the most salient themes that emerged from the qualitative data was students' perception that Fishbone-Oriented Instruction helped them visually structure and connect ideas. Through the use of fishbone diagrams, students were able to organize scientific information systematically, identify key concepts, and recognize relationships among causes related to scientific phenomena. Although these skills were reflected quantitatively in the normalized gain results discussed in Subsection 3.1, students' narratives provide deeper insight into how such understanding was constructed during learning.

During interviews, students emphasized that the fishbone diagram provided a clear visual structure that made complex topics easier to understand. For instance, one student stated:

EGP20: *"It gives a clear visual of ideas. Na-oorganize niya yong mga ideas para madaling maintindihan."*

(It gives a clear visual of ideas. It organizes ideas so that they are easier to understand.)

Another student described how the diagram helped connect individual and group ideas, making learning more meaningful:

EGP44*: "Using fishbone diagram, it made science interesting for me dahil mas naiintindihan ko ang mga topics and nae-co-connect namin ang bawat ideas namin."*

(Using the fishbone diagram made science interesting for me because I understood the topics better and we were able to connect each of our ideas.)

These interview responses indicate that FOI supported students in integrating information into coherent conceptual frameworks rather than processing ideas in isolation. Visual organization is a critical component of conceptual understanding because it allows learners to externalize their thinking and identify relationships among concepts more effectively (Wang *et al*., 2018; Chang *et al*., 2019).

This theme is further illustrated through students' journal entries. As previously shown in Figure 3, one student reflected on how the fishbone diagram helped organize ideas and identify relationships among concepts, enabling clearer and more structured thinking during the lesson. Similarly, **Figure 4** demonstrates another student's reflection on how the fishbone diagram provided a visual framework that broke down complex problems into categorized causes, making it easier to brainstorm and understand relationships among different factors.

Although these figures were introduced earlier to support conceptual gains, their reinterpretation here highlights students' subjective experiences of visual structuring as a learning process. The journal entries show that students consciously recognized the diagram as a cognitive tool that helped them organize thoughts and connect ideas meaningfully. Such findings are consistent with constructivist perspectives, which emphasize that learners actively build understanding by organizing information through meaningful representations.

From a sociocultural perspective, the shared construction of fishbone diagrams during group activities also reflects learning as a socially mediated process. As students collaborated to populate the diagram, they negotiated meanings, clarified ideas, and built shared understanding, consistent with view of learning through social interaction.

Overall, students' perceptions indicate that Fishbone-Oriented Instruction effectively supported visual structuring and connection of ideas, not only contributing to improved conceptual understanding but also shaping how students approached and made sense of scientific information. This theme provides a conceptual bridge to the next theme, which focuses on how FOI enhanced students' understanding of cause-and-effect relationships in science.

3.4. Understanding Cause-and-Effect Relationships

Another central theme that emerged from the qualitative data is students' improved understanding of cause-and-effect relationships through the use of FOI. Students consistently reported that the fishbone diagram helped them identify root causes of scientific problems, categorize contributing factors, and connect these causes to observable effects. This theme is particularly significant in science education, where conceptual understanding depends heavily on students' ability to reason causally rather than memorize isolated facts (Driver *et al*., 2000).

During individual interviews, students explicitly described how FOI supported their causal reasoning. One participant explained that the diagram allowed them to break down a main issue into smaller, more manageable components:

EGP52: *"Ok po ako sa ganitong uri ng pagtuturo na gumagamit ng fishbone diagram kasi na-iidentify namin ang mga causes/categories and sub-causes and sub-categories sa isang main issue or problem."*

(I am okay with this kind of teaching that uses a fishbone diagram because we can identify the causes/categories and sub-causes and sub-categories of a main issue or problem.)

This response illustrates that students developed a structured approach to analyzing scientific problems by systematically identifying multiple layers of causation. Such analytical skills are essential for conceptual understanding, as they enable learners to recognize relationships among variables and construct explanations grounded in scientific reasoning (Patel & Pradhan, 2018).

Another student emphasized how the fishbone diagram visually clarified the relationship between causes and a central scientific issue:

EGP30: *"Sa pamamagitan ng diagram, pinapakita ang mga causes ay konektado sa main problem or issue, for example biodiversity." (Through the diagram, the causes are shown to be connected to the main problem or issue, such as biodiversity.)*

These interview excerpts suggest that FOI helped students move from fragmented understanding toward integrated causal models of scientific phenomena. By visually mapping causes and sub-causes, learners were able to see how multiple factors interact to produce specific outcomes, which is a core aspect of scientific literacy.

Students' journal entries further support this theme by providing concrete examples of how learners applied causal reasoning to real-world environmental issues. As shown in **Figure 5**, one student identified human activities such as pollution, deforestation, and climate change as root causes of biodiversity loss, demonstrating an awareness of anthropogenic factors in environmental degradation. Similarly, **Figure 6** presents another student's reflection on how deforestation, pollution, and climate change contribute to habitat destruction and species loss. The student explicitly connected these causes to broader environmental consequences, indicating an understanding of how human actions lead to ecological imbalance.

These journal entries reveal that students were able to apply classroom learning to authentic contexts by analyzing environmental problems through a cause-and-effect lens. This ability to transfer scientific concepts to real-world situations is a strong indicator of deep conceptual understanding and meaningful learning. Rather than simply listing causes or effects, students demonstrated the ability to link human activities to environmental outcomes in a logical and coherent manner.

The development of causal reasoning observed in this study aligns with previous research showing that visual reasoning strategies, such as fishbone diagrams and concept mapping, enhance students' ability to analyze relationships among variables and construct explanations in science learning (Chang *et al*., 2019; Suryani & Hendri, 2019). By providing a structured visual framework, FOI reduced cognitive overload and supported students in organizing complex information into comprehensible patterns (Wang *et al*., 2018).

From a constructivist perspective, the fishbone diagram functioned as a cognitive scaffold that guided learners in constructing knowledge through active analysis and reflection. As students identified causes, grouped related factors, and discussed their interconnections, they engaged in higher-order thinking processes that are central to conceptual change (Driver *et al*., 2000). This process reflects the idea that learning occurs most effectively when students actively reorganize their understanding rather than passively receive information.

Moreover, the emphasis on identifying human-induced environmental problems highlights the relevance of FOI in promoting education for sustainable development. As students analyzed issues such as pollution, deforestation, and climate change, they demonstrated increased awareness of the role of human actions in environmental degradation. This awareness is closely aligned with the goals of science education that seek to foster responsible citizenship and informed decision-making related to sustainability issues (OECD, 2019).

The interview and journal data also suggest that FOI encouraged students to think critically about responsibility and consequences. By explicitly linking causes to effects, students were able to recognize that environmental problems are not isolated events but are the result of interconnected human and natural systems. This systems-oriented thinking is a key component of scientific literacy and supports students' ability to engage with complex global challenges.

Overall, the findings under this theme indicate that Fishbone-Oriented Instruction effectively enhanced students' understanding of cause-and-effect relationships in science. The convergence of interview responses and journal reflections provides strong evidence that students developed analytical skills that enabled them to identify root causes, evaluate contributing factors, and connect these causes to observable effects. These qualitative insights help explain the quantitative learning gains reported earlier and underscore the role of FOI as an instructional strategy that supports deep conceptual understanding rather than surface-level learning.

This enhanced understanding of causal relationships also serves as a foundation for the next theme, which examines how Fishbone-Oriented Instruction influenced students' engagement, interest, collaboration, and participation during science lessons.

3.5. Enhanced Engagement, Interest, Collaboration, and Participation

Another prominent theme that emerged from the qualitative analysis is the enhancement of students' engagement, interest, collaboration, and participation during science lessons through FOI. Students consistently reported that learning activities became more engaging and enjoyable when they were actively involved in constructing fishbone diagrams, discussing ideas with peers, and collaboratively analyzing scientific problems. This theme highlights the affective and social dimensions of learning that accompany the cognitive gains discussed in previous sections.

During the interviews, students frequently expressed positive emotional responses toward FOI, emphasizing that the instructional approach encouraged teamwork and active participation. One student explained:

EGP44: *"I am happy because we have this new technique of teaching that enables us to work together as a group to share our thoughts and ideas."*

This response suggests that FOI fostered a collaborative learning environment where students felt comfortable sharing ideas and contributing to group discussions. Such collaborative engagement is a key factor in promoting meaningful learning, as social interaction allows learners to negotiate meaning, clarify misconceptions, and build shared understanding.

Another student highlighted how FOI empowered all group members to participate actively:

EGP67: *"I appreciated the use of the fishbone diagram because I learned the topic very well. It allows us to participate. The group members are empowered to participate in the completion of the fishbone activity."*

This statement indicates that FOI reduced passive learning and encouraged equitable participation among students. By assigning shared responsibility for completing the fishbone diagram, the instructional strategy ensured that learners were not merely observers but active contributors to the learning process. Active participation has been shown to increase students' motivation and engagement, which are critical factors in sustaining interest in science learning.

Students also emphasized that FOI made learning more interesting by transforming abstract science topics into interactive and hands-on activities. One participant explained:

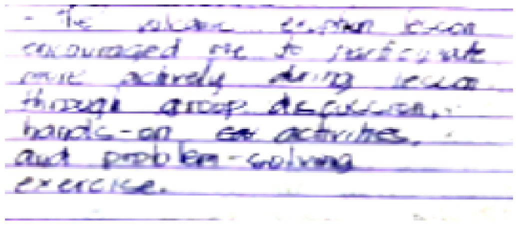
EGP20: *"Nagagamit ng isa isa ang kani-kanilang idea base sa kanilang nabasa sa topic na binigay sa amin na assignment. It allows us to work together and present our group output."*

(Each of us is able to use our own ideas based on what we read about the assigned topic. It allows us to work together and present our group output.)

This response illustrates that FOI encouraged students to prepare, contribute individual ideas, and synthesize them collaboratively. Such processes promote deeper engagement by connecting independent learning with group interaction, thereby reinforcing both responsibility and participation.

Students' journal entries further corroborate these interview findings. As illustrated in **Figure 7**, one student reflected on how group discussions and collaborative fishbone activities increased their engagement and motivation during the lesson. Similarly, **Figure 8** shows another student's journal entry describing how working with peers and actively participating in the fishbone activity made learning more enjoyable and meaningful.

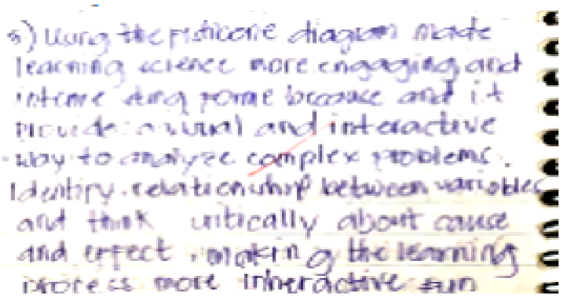
4. *In what did the fishbone activity encouraged you to participate more actively during the lesson?*



EGP30: *The volcanic eruption lesson encouraged me to participate more actively during the lesson through group discussions, hands on activities and problem solving exercises.* (The volcanic eruption lesson encouraged me to participate more actively during the lesson through group discussions, hands on activities and problem solving exercises.)

Figure 7. Journal entry of EGP30 dated September 18, 2025.

3. *Did using Fishbone activity make learning engaging or interesting for you? Why or why not?*



EGP48: *Using the Fishbone diagram made learning Science more engaging and interesting for me because it provide a visual and interactive way to analyze complex problems, identify relationship between variables and think critically about cause and effect, making the learning more interactive and fun.* (Using the Fishbone diagram made learning Science more engaging and interesting for me because it provide a visual and interactive way to analyze complex problems, identify relationship between variables and think critically about cause and effect, making the learning more interactive and fun.)

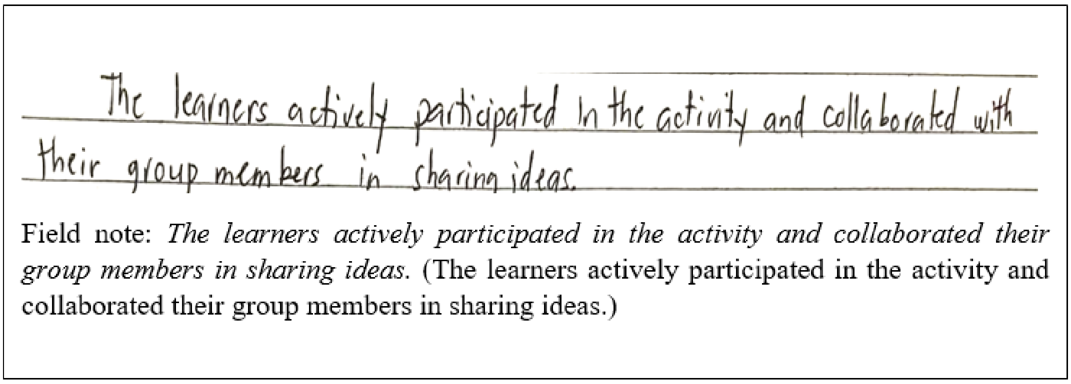
Figure 8. Journal entry of EGP48 dated September 18, 2025

p- ISSN 2828-3287 e- ISSN 2828-3295

These reflections indicate that FOI created a learning environment characterized by active involvement and shared responsibility. The hands-on and interactive nature of the strategy transformed students from passive recipients of information into active participants who collaboratively constructed knowledge. Such engagement is consistent with research showing that participatory and cooperative learning strategies enhance students' interest and motivation in science education (Sangchan & Boonma, 2019).

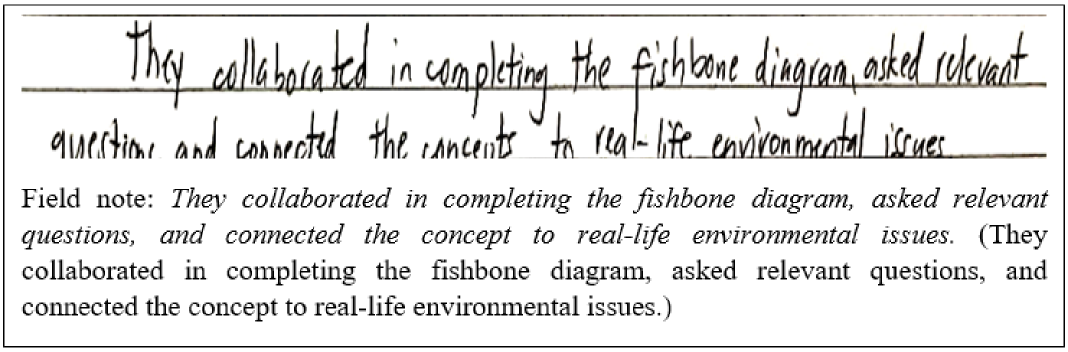
Observational data from the researcher's field notes provide additional evidence supporting this theme. As documented in the field notes, students actively collaborated with group members, shared ideas, and demonstrated responsibility in completing assigned tasks. For instance, field notes recorded that learner "actively participated in the activity and collaborated with their group members in sharing ideas," indicating high levels of engagement throughout the lesson.

This observation is further illustrated in **Figure 9**, which presents an excerpt from the researcher's field notes highlighting students' active participation and collaboration during the fishbone activity. Another field note excerpt, shown in **Figure 10**, describes how students collaborated in completing the fishbone diagram, asked relevant questions, and connected scientific concepts to real-life environmental issues.


The learners actively participated in the activity and collaborated with their group members in sharing ideas.

Field note: *The learners actively participated in the activity and collaborated their group members in sharing ideas.* (The learners actively participated in the activity and collaborated their group members in sharing ideas.)

Figure 9. Excerpt from researcher's field note dated October 9, 2025


They collaborated in completing the fishbone diagram, asked relevant questions and connected the concepts to real-life environmental issues

Field note: *They collaborated in completing the fishbone diagram, asked relevant questions, and connected the concept to real-life environmental issues.* (They collaborated in completing the fishbone diagram, asked relevant questions, and connected the concept to real-life environmental issues.)

Figure 10. Excerpt from researcher's field note dated October 2, 2025.

These observational findings demonstrate that FOI not only increased students' engagement but also promoted higher-quality participation characterized by questioning, discussion, and application of concepts. Such behaviours are indicative of deep engagement, where students are cognitively, emotionally, and socially invested in the learning process.

From a theoretical perspective, the enhanced engagement and collaboration observed in this study align with sociocultural theory, which emphasizes learning through social interaction and collaborative problem-solving. FOI provided a structured context in which students could interact meaningfully, exchange ideas, and co-construct understanding. This social dimension of learning likely contributed to the positive perceptions and sustained interest reported by students.

Furthermore, the findings support constructivist views of learning, which posit that students learn more effectively when they are actively involved in exploring, discussing, and reflecting on content rather than passively receiving information. By engaging students in hands-on and participatory activities, FOI fostered an environment conducive to exploration and inquiry, thereby enhancing students' motivation and interest in science learning.

Overall, the qualitative evidence indicates that Fishbone-Oriented Instruction significantly enhanced students' engagement, interest, collaboration, and participation in science lessons. Through interactive group activities, visual organization, and shared responsibility, FOI created a dynamic learning environment that encouraged active involvement and sustained interest. These affective and social outcomes complement the cognitive gains reported earlier and highlight the holistic impact of FOI on students' learning experiences.

This theme naturally leads to the final theme, which examines how Fishbone-Oriented Instruction encouraged students to value idea sharing and expression, further strengthening their confidence and communication skills in science learning.

3.6. Valuing Idea Sharing and Student Expression

The final theme that emerged from the qualitative analysis highlights how FOI encouraged students to value idea sharing and expression during science learning activities. Students consistently reported that the instructional approach created opportunities for them to voice their thoughts, exchange perspectives, and build upon each other's ideas in a supportive learning environment. This theme underscores the role of FOI in fostering students' communication skills, confidence, and sense of ownership over their learning.

During the interviews, students explicitly described how the fishbone diagram enabled all group members to contribute ideas and engage in meaningful discussion. One student stated: EGP67: *"It enables the whole group to participate and share their ideas. It encourages us to think deeply about the factors contributing to a problem."*

This response indicates that FOI promoted collective thinking by encouraging students to articulate their understanding and consider multiple viewpoints. Such practices are essential for developing scientific reasoning, as learners must explain, justify, and refine ideas through dialogue and reflection.

Another student emphasized how FOI supported comprehension through shared understanding:

EGP8: *"It enables us to read and share what we understood."*

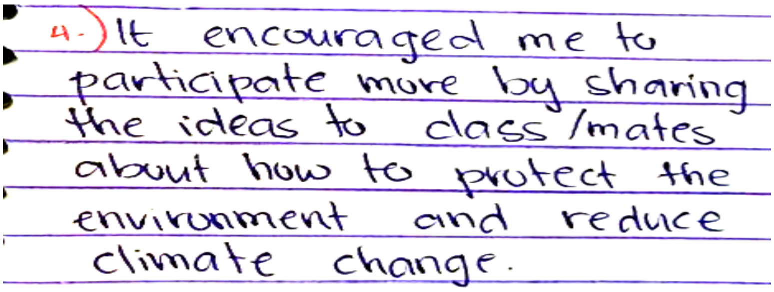
These interview excerpts suggest that FOI transformed the classroom into a dialogic learning space were students actively constructed knowledge together. Rather than relying solely on teacher explanations, learners were encouraged to express their interpretations, listen to peers, and negotiate meaning collaboratively. This shift from passive reception to active expression aligns with constructivist principles that emphasize learning as an interactive and participatory process.

Students' journal entries further reinforce this theme by illustrating how FOI encouraged expression and communication skills alongside conceptual learning. As shown in **Figure 11**, one student reflected on how sharing ideas during fishbone activities helped them understand environmental issues more deeply while also improving their ability to communicate thoughts to classmates.

p- ISSN 2828-3287 e- ISSN 2828-3295

Similarly, **Figure 12** presents another student's journal entry describing how being given opportunities to contribute ideas increased motivation and engagement during science lessons.

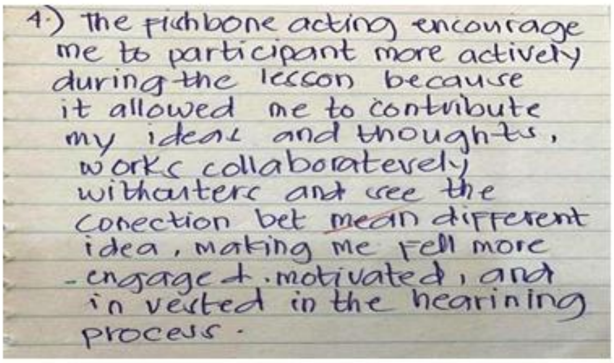
3. *In what did the fishbone activity encourage you participate more actively during the lesson?*


4.) It encouraged me to
participate more by sharing
the ideas to class/mates
about how to protect the
environment and reduce
climate change.

EGP 34: *It encouraged me to participate more by sharing my ideas to my classmates on how to protect the environment and reduce climate change.* (It encouraged me to participate more by sharing my ideas to my classmates on how to protect the environment and reduce climate change.)

Figure 11. Journal entry of EGP34 dated October 2, 2025.

4. *In what did the fishbone activity encourage you participate more actively during the lesson?*


4.) The fishbone acting encourage
me to participant more actively
during the lesson because
it allowed me to contribute
my ideas and thoughts,
works collaboratevely
withothers and see the
conection bet mean different
idea, making me fell more
engaged, motivated, and
in vested in the hearining
process.

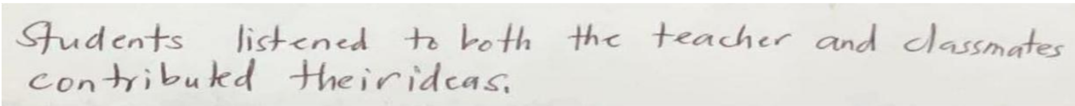
EGP 55: *The fishbone activity encourage me to participant more actively during the lesson because it allowed me to contribute my ideas and thoughts, works collaboratively with others, and see the connections between different ideas, making me feel more engaged, motivated, and invested.* (The fishbone activity encouraged me to participate more actively during the lesson because it allowed me to contribute my ideas and thoughts, work collaboratively with others, and see the connections between different ideas, making me feel more engaged, motivated, and invested.)

Figure 12. Journal entry of EGP55 dated October 2, 2025.

These reflections indicate that FOI not only supported cognitive development but also nurtured affective outcomes such as confidence, motivation, and willingness to participate. When students felt that their ideas were valued, they became more invested in the learning process and more eager to engage in discussion. Such outcomes are consistent with research suggesting that student-centered and dialogic instructional strategies enhance both engagement and learning quality (Sangchan & Boonma, 2019).

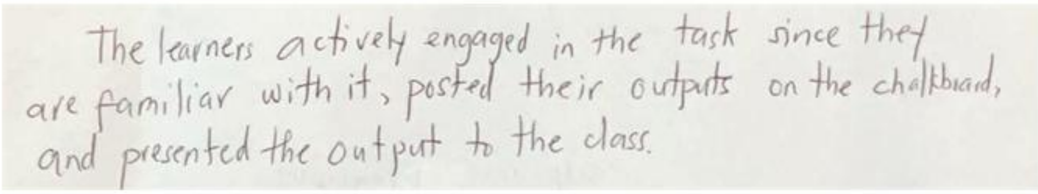
Observational data from the researcher's field notes provide additional evidence supporting this theme. Field notes documented that student listened attentively to both the teacher and their peers, contributed ideas during group discussions, and confidently presented their outputs to the class. These behaviors reflect an environment where idea sharing was normalized and encouraged.

This is illustrated in **Figure 13**, which presents an excerpt from the researcher's field notes describing students' active listening and idea contribution during fishbone activities. Another field note excerpt, shown in **Figure 14**, highlights how students posted their group outputs on the chalkboard and presented them to the class, demonstrating confidence and ownership of their work.


Students listened to both the teacher and classmates contributed theirideas.

Field Note: Students listened to both the teacher and their peers and contributed ideas.

Figure 13. Excerpt from Field Note dated September 4, 2025.


The learners actively engaged in the task since they are familiar with it, posted their outputs on the chalkboard, and presented the output to the class.

Field Note: The learners actively engaged in the task since they are familiar with it, posted their outputs on the chalkboard, and presented the output to the class.

Figure 14. Excerpt from field note dated September 18, 2025.

These observations indicate that FOI fostered a classroom culture that valued expression, collaboration, and shared responsibility for learning. By providing structured opportunities for students to articulate ideas and present group outputs, FOI helped develop communication skills that are essential for scientific literacy and lifelong learning.

From a sociocultural perspective, the emphasis on idea sharing and expression reflects the view that learning is fundamentally social and mediated through language and interaction. As students discussed causes, effects, and solutions during fishbone activities, they engaged in meaningful discourse that supported the internalization of scientific concepts. The fishbone diagram functioned as a shared artifact that anchored discussion and facilitated collective reasoning.

Moreover, the opportunity to express ideas freely contributed to students' sense of agency and empowerment. When learners were encouraged to contribute their thoughts without fear of judgment, they became more confident in their abilities and more willing to engage in complex problem-solving tasks. This empowerment is a critical component of holistic education, as it supports not only academic achievement but also personal and social development.

Overall, the findings under this theme demonstrate that Fishbone-Oriented Instruction effectively encouraged students to value idea sharing and expression as integral parts of science learning. By creating an interactive and supportive learning environment, FOI enabled students to communicate ideas, collaborate with peers, and develop confidence in expressing scientific understanding. These outcomes complement the cognitive gains and engagement benefits discussed in previous sections, highlighting the comprehensive impact of FOI on students' learning experiences.

Taken together, the four themes discussed in the above section (visual structuring and connection of ideas, understanding cause-and-effect relationships, enhanced engagement and collaboration, and valuing idea sharing and expression) illustrate that Fishbone-Oriented Instruction supported learning across cognitive, social, and affective domains. These findings provide strong qualitative evidence that explains the quantitative improvements in conceptual understanding reported earlier and underscore the effectiveness of FOI as a holistic instructional strategy in science education.

4. CONCLUSION

Overall, the findings under this theme demonstrate that Fishbone-Oriented Instruction effectively encouraged students to value idea sharing and expression as integral parts of science learning. By creating an interactive and supportive learning environment, FOI enabled students to communicate ideas, collaborate with peers, and develop confidence in expressing scientific understanding. These outcomes complement the cognitive gains and engagement benefits discussed in previous sections, highlighting the comprehensive impact of FOI on students' learning experiences.

Taken together, the four themes discussed in the above section (visual structuring and connection of ideas, understanding cause-and-effect relationships, enhanced engagement and collaboration, and valuing idea sharing and expression) illustrate that Fishbone-Oriented Instruction supported learning across cognitive, social, and affective domains. These findings provide strong qualitative evidence that explains the quantitative improvements in conceptual understanding reported earlier and underscore the effectiveness of FOI as a holistic instructional strategy in science education.

5. ACKNOWLEDGMENT

We would also like to express our deep appreciation to Dr. Josette T. Biyo, former Director of the Department of Science and Technology, Science Education Institute (DOST-SEI), for the scholarship opportunity that made this academic journey possible. Finally, the researcher is sincerely grateful to the principal, Science teachers, and students of Bacarat Memorial National High School, Batch 2025–2026, for their cooperation and participation, which greatly contributed to the success of this study.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183–198.

Chang, K. E., Sung, Y. T., and Chen, S. F. (2019). The effect of concept mapping-based causal reasoning instruction on students' scientific understanding and reflective thinking. *International Journal of Science Education, 41*(6), 793–814.

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73–105.

Clary, R., and Wandersee, J. (2010). Fishbone diagrams: Organize reading content with a "bare bones" strategy. *Science Scope, 33*(9), 31–37.

Dogru, M. (2008). The application of the problem-solving method on science teacher trainees on the solution of the environmental problems. *Journal of Environmental and Science Education, 3*(1), 9–18.

Driver, R., Squires, A., Rushworth, S., and Wood-Robinson, V. (2000). Making sense of secondary science: A review of research on conceptual change. *Studies in Science Education, 35*, 1–64.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74.

Hidayat, A., and Rohman, F. (2019). Effect of problem-based and visual mapping instruction on analytical skills in science. *Journal of Science Education Research, 13*(2), 88–97.

Hidayat, A., and Rohman, F. (2019). Effect of problem-based and visual mapping instruction on analytical skills in science. *Journal of Science Education Research, 13*(2), 88–97.

Hmelo-Silver, C. E., Duncan, R. G., and Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark. *Educational Psychologist, 42*(2), 99–107.

Istikomah, I. (2017). The influence of the problem-based learning model with fishbone diagram on students' critical thinking ability. *Indonesian Journal of Informatics Education, 1*(2), 10–17.

Latha, S., and Prasad, P. (2019). Using Fishbone Diagram as a pedagogical tool to enhance analytical thinking in science education. *International Journal of Innovative Technology and Exploring Engineering, 8*(12), 4565–4569.

Latha, S., and Prasad, P. (2019). Using Fishbone Diagram as a pedagogical tool to enhance analytical thinking in science education. *International Journal of Innovative Technology and Exploring Engineering, 8*(12), 4565–4569.

Patel, D., and Pradhan, M. (2018). Impact of concept mapping and visual reasoning strategies on students' engagement and conceptual learning in physics*. International Journal of Science and Mathematics Education, 16*(7), 1293–1312.

Sangchan, S., and Boonma, T. (2019). Developing analytical thinking skills through visual and cooperative learning approaches in science classrooms. *Journal of Education and Learning, 8*(3), 123–132

Soren, D. D., Barman, J., and Biswas, B. (2023). A comprehensive review on the impact of climate change on streamflow: Current status and perspectives. *River Conservation and Water Resource Management*, 117–150.

Suryani, L., and Hendri, D. (2019). Using Fishbone Diagram to improve students' analytical and problem-solving skills in science learning. *International Journal of Instruction, 12*(3), 243–258.

Wang, M. T., Lee, M., and Chen, S. (2018). Effects of concept mapping on students' learning achievements and cognitive load in science education. *Educational Technology and Society, 21*(4), 178–190.