

Effects of Fishbone-Oriented Instruction on Students' Attitude in Science

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Abstract

This study examined the effects of Fishbone-Oriented Instruction (FOI) on the attitudes toward Science of Grade 9 students at Bacarat Memorial National High School during the School Year 2025–2026. Anchored in constructivist and sociocultural learning principles and the cognitive, affective, and behavioral dimensions of attitude, the study employed a mixed-method approach. The quantitative component used a one-group pretest–posttest quasi-experimental design, while the qualitative component explored students' perceptions and experiences. Participants were 68 students from two intact Grade 9 sections selected through purposive sampling. The intervention was implemented for eight weeks. Data were collected using the 23-item Attitude towards Science Scale (AtSS), individual interviews, student journal entries, and teacher-researcher field notes. Descriptive statistics and the Wilcoxon Signed-Rank Test were used for quantitative analysis, while qualitative data were examined through thematic analysis. Before the intervention, 55.9% of the students had negative attitudes and 44.1% had very negative attitudes toward Science. After the intervention, 86.8% demonstrated very positive attitudes and 13.2% showed positive attitudes. The mean score increased from 41.09 to 77.77, with a significant difference between pretest and posttest scores ($Z = -7.172$, $p = .000$). Qualitative findings showed that FOI helped students visually organize information, understand cause-and-effect relationships, participate actively, collaborate with classmates, and express their ideas. The study concludes that FOI is an effective instructional strategy for improving students' attitudes, engagement, and learning experiences in Science. Future studies should examine its long-term effects and integration with other active learning approaches. The study supports SDG 4—Quality Education by promoting learner-centered, inclusive, and meaningful Science instruction. It contributes to educational and institutional sustainability by providing schools with an adaptable and resource-conscious strategy for strengthening sustained learner engagement and scientific literacy.

Keywords: Attitude Toward Science, Educational Sustainability, Fishbone-Oriented Instruction, Science Education, Visual Learning

1. Introduction

Science education is essential in developing scientific literacy, critical thinking, and the competencies learners need to participate in national development and a knowledge-based society. However, Filipino students continue to experience difficulties in scientific literacy, engagement, and attitudes toward science. Since students' attitudes influence their interest, motivation, participation, persistence, and academic performance, science instruction must provide active, meaningful, and collaborative learning experiences. Fishbone-Oriented Instruction (FOI), which uses a structured cause-and-effect diagram to organize information and examine relationships among concepts, may provide such an experience. This study therefore investigates the effects of FOI on the attitude toward Science of Grade 9 students in a Philippine public secondary school.

The Philippine K to 12 Science Curriculum emphasizes inquiry-based learning, critical thinking, and scientific literacy to prepare learners for national and global participation. Despite these curricular reforms, the Programme for International Student Assessment 2018 showed that many Filipino students did not reach the minimum proficiency level in scientific literacy, indicating continuing concerns regarding science learning, engagement, and attitudes (OECD, 2019). Attitude toward science is an important affective factor in learning. Students who perceive science as interesting, relevant, and enjoyable are more likely to participate actively and persist in challenging activities. In contrast, learners with negative perceptions may lose interest and become less involved in classroom tasks. Osborne et al. (2003) observed that attitudes toward science commonly decline as students advance to higher grade levels, contributing to reduced engagement. International assessments similarly indicate that students' dispositions toward learning affect their academic outcomes (OECD, 2019). In the Philippine context, Picardal and Sanchez (2022) found that attitudes toward science are significantly associated with classroom engagement and science-related behaviors. These concerns demonstrate the need for instructional strategies that move beyond passive listening and memorization. Science teaching should provide opportunities for learners to organize information, explore relationships, communicate ideas, and collaboratively construct understanding.

Fishbone-Oriented Instruction is derived from the Ishikawa cause-and-effect diagram, which was originally developed to identify and organize the multiple factors contributing to a particular problem or outcome (Ishikawa, 1986). The central problem or outcome is positioned at the head of the diagram, while its branches represent related categories and possible causes. Although initially used in business and industry, the diagram has been adapted as a classroom strategy for organizing ideas and illustrating relationships among concepts. As a structured visual-mapping approach, FOI is consistent with research on graphic organizers and concept maps. Chang et al. (2002) found that concept mapping increased students' learning interest, while Sarker and Salahuddin (2018) reported that visual-mapping tools improved students' attitudes toward learning. Nesbit and Adesope (2006) further explained that concept and knowledge maps promote understanding and engagement by enabling learners to organize, connect, and integrate information meaningfully. In science instruction, FOI guides learners in identifying relevant factors, grouping related concepts, analyzing possible causes, and examining cause-and-effect relationships. Research indicates that learners who use fishbone diagrams may demonstrate stronger understanding and thinking skills than those taught through conventional approaches (Al-Zahrani, 2020; Munawir, 2022). The strategy may also support visually oriented and activity-based learners by helping them recognize patterns, connect ideas, and summarize information (Dewi and Hidayat, 2020). Another major theme in the literature concerns the relationship between instructional practices and students' attitudes toward science. According to Ajzen (2001), attitude includes cognitive, affective, and behavioral components. In science education, these components involve students' beliefs about science, their emotional responses to the subject, and their willingness to participate in science-related activities. Students' attitudes consequently influence their motivation and academic performance (Osborne et al. 2003; Shah and Mahmood, 2011). Students with positive attitudes generally demonstrate greater interest, effort, curiosity, and willingness to explore unfamiliar ideas. Positive feelings toward science are also associated with stronger academic performance (Salta and Tzougraki, 2004). Conversely, boredom, anxiety, and negative perceptions can discourage learners from joining discussions, asking questions, and attempting difficult tasks. The manner in which science is taught therefore plays a critical role in shaping students' attitudes. Lessons involving inquiry, investigations, and hands-on activities tend to develop more favorable attitudes than instruction dominated by lectures (Aktamiş, Hiçde, & Özden, 2016). Active learning helps students recognize science as understandable, useful, interesting, and connected to real-life experiences. Positive attitudes also encourage critical thinking, problem-solving, and the application of scientific knowledge in authentic situations (Osborne et al., 2003). FOI incorporates these visual, analytical, active, and collaborative elements. By allowing students to construct diagrams, discuss possible causes, classify information, and communicate their interpretations, the strategy may improve both their understanding of science concepts and their attitudes toward learning.

At the local level, the study focuses on 68 Grade 9 students from two intact sections at Bacarat Memorial National High School during the School Year 2025–2026. The setting provides an opportunity to examine whether a visual and collaborative instructional approach can address students' attitudes toward Science within an actual public secondary-school classroom. Nationally, the study responds to the need to strengthen scientific literacy and classroom engagement among Filipino learners. The difficulties reflected in international assessment results indicate that curricular reforms must be supported by appropriate classroom strategies that encourage active participation and meaningful understanding (OECD, 2019). The relationship between attitudes, engagement, and science-related behaviors in the Philippine setting further supports the importance of affective development in science education, as demonstrated by Picardal and Sanchez (2022). Globally, the study contributes to continuing discussions on declining student interest in science, the influence of attitudes on academic outcomes, and the value of learner-centered instructional approaches. It also extends research on visual organizers and concept-mapping techniques by examining the Fishbone Diagram as a specific instructional strategy for junior high school science.

The conceptual foundation of FOI originates from the Ishikawa diagram, which organizes the possible causes of a problem or outcome into a systematic visual structure (Ishikawa, 1986). In the classroom, this structure enables students to break down complex science concepts, identify major factors, classify supporting information, and understand relationships among ideas. FOI is also consistent with constructivist learning. Learners develop understanding more effectively when they actively organize, interpret, and connect information instead of merely receiving it from the teacher (Bruner, 1996). Constructing a fishbone diagram requires students to examine information, make decisions about relevant categories, and build their own representation of the lesson. The collaborative implementation of FOI is supported by sociocultural learning theory. When students construct diagrams in groups, they exchange ideas, ask questions, explain their reasoning, and correct misunderstandings through interaction with their classmates (Vygotsky, 1978). The teacher and peers therefore provide guidance and social support while learners progressively develop understanding. The study is further informed by the cognitive, affective, and behavioral view of attitude presented by Ajzen (2001). FOI may influence students' beliefs about the comprehensibility and relevance of science, their feelings of interest or enjoyment, and their willingness to participate in learning activities. The study consequently treats attitude toward Science as a multidimensional learning outcome that may be shaped by classroom experiences.

Previous studies have established the educational value of visual mapping, concept mapping, active learning, and fishbone diagrams. The literature suggests that these strategies can enhance conceptual organization, analytical thinking,

engagement, motivation, and attitudes toward learning. However, limited empirical evidence is available regarding the effects of Fishbone-Oriented Instruction specifically on junior high school students' attitudes toward Science in the Philippine setting. Existing research also provides insufficient context-specific evidence on how Filipino Grade 9 students perceive FOI as a learning strategy. Although fishbone diagrams have been applied in different educational and disciplinary contexts, their influence on the cognitive, affective, and behavioral dimensions of science attitudes requires further investigation. The present study addresses these gaps by examining students' attitudes before and after exposure to FOI and exploring their perceptions of the strategy. Its findings may provide evidence for teachers seeking instructional approaches that make science lessons more organized, interactive, collaborative, and motivating.

The study aligns most directly with SDG 4 – Quality Education. It examines an instructional strategy intended to improve learner engagement, attitudes toward Science, collaborative participation, and meaningful understanding. These outcomes support the provision of inclusive and effective learning experiences that help students develop scientific literacy and relevant cognitive and affective competencies. FOI may contribute to quality education by making complex scientific relationships easier to organize and understand. Its visual and collaborative characteristics may also provide learners with different ways to participate, communicate, and construct knowledge. The study therefore supports efforts to strengthen learner-centered science instruction and improve the quality of classroom teaching and learning.

The study is relevant primarily to educational sustainability because it investigates a practical strategy for maintaining students' interest, participation, and positive attitudes toward Science. Sustainable education requires not only access to schooling but also learning experiences that encourage learners to remain engaged, confident, and willing to continue developing their knowledge. The research also connects science education, educational psychology, instructional design, and collaborative learning. Its examination of attitude recognizes that sustainable learning involves cognitive understanding, positive emotional responses, and active participation. By addressing these interconnected dimensions, FOI may support teaching practices that are responsive to different learning needs. The study also has implications for institutional sustainability by providing evidence that schools and teachers may use when selecting classroom interventions. An adaptable and resource-conscious visual strategy such as FOI may help teachers create more participatory learning environments without depending on highly specialized instructional resources. Finally, improving students' attitudes and scientific literacy may contribute to socio-economic sustainability by preparing learners to think critically, solve problems, and participate productively in a knowledge-based society. Strengthening interest in science can support the continuing development of learners who are better prepared to understand scientific issues and contribute to national development.

2. Material and methods

2.1 Research Design

The study used a mixed-method research design integrating quantitative and qualitative approaches. The quantitative component employed a one-group pretest–posttest quasi-experimental design involving two intact Grade 9 sections, as described by Creswell (2014). The same participants completed an attitude assessment before and after receiving Fishbone-Oriented Instruction. The qualitative component explored the students' perceptions, experiences, and reflections regarding the instructional strategy. Data were collected through individual interviews, student journal entries, and the teacher-researcher's field notes. The qualitative findings were used to explain how and why the intervention influenced students' attitudes toward Science and to strengthen the interpretation of the quantitative results.

2.2 Locale of the Study

The study was conducted at Bacarat Memorial National High School during the School Year 2025–2026. Two intact Grade 9 sections from the school participated in the implementation of Fishbone-Oriented Instruction.

2.3 Respondents of the Study

The participants were 68 Grade 9 students enrolled at Bacarat Memorial National High School during the School Year 2025–2026. The individual student served as the unit of analysis, and all quantitative scores and qualitative responses were analyzed at the student level. Both intact sections received Fishbone-Oriented Instruction and belonged to the experimental group. To protect the participants' identities, each student was assigned a code beginning with EGP, representing Experimental Group Participant, followed by a numerical designation.

2.4 Sample and Sampling Procedure

The study used purposive sampling involving two intact Grade 9 sections that met the research requirements. Random assignment was not conducted because existing school policies and class schedules did not allow students to be transferred or reassigned to different groups. The participants had exposure to the targeted Grade 9 Science topics and maintained consistent attendance during the intervention period. No matching of participants was performed, and all students in the selected sections received the same instructional treatment.

2.5 Research Instrument

The primary quantitative instrument was the Attitude towards Science Scale (AtSS), consisting of 23 items adopted from the work of Zubair Ahmad Shah and Nasir Mahmood (2011). The instrument measured students' multidimensional attitudes toward Science using a five-point Likert scale, with responses ranging from 1 for "never" to 5 for "always." It contained 18 positive statements and five negative statements. Items 16, 19, 20, 22, and 23 were reverse-coded during data analysis. The original instrument had a reliability coefficient of 0.86. For the present study, it was pilot-tested among 40 Grade 10 students from Lake Lanao National High School and obtained a Cronbach's alpha coefficient of 0.67, which was considered acceptable for classroom-based affective research. Content validity was established through a review conducted by two Science educators who examined the clarity, relevance, and alignment of the items with the construct of attitude toward Science. Students' scores were interpreted using the categorization scheme adapted from Pratiwi et al. (2018). Scores from 0 to 23 represented a very negative attitude, 24 to 46 indicated a negative attitude, 47 to 69 represented a neutral attitude, 70 to 92 indicated a positive attitude, and 93 to 115 represented a very positive attitude. A six-question interview guide was developed to explore the students' perceptions of Fishbone-Oriented Instruction. The open-ended questions examined their overall experiences, emotional responses, perceived benefits, encountered challenges, conceptual understanding, topics for which the strategy was most effective, and willingness to recommend its future use. Probing questions were used to obtain clarification and elaboration. Each interview lasted approximately 15–20 minutes and was audio-recorded with the participants' consent. Student journal entries were also used to document observations, thoughts, learning experiences, realizations, engagement, and possible changes in attitudes toward Science. The teacher-researcher maintained field notes during or immediately after each lesson to record students' behaviors, interactions, participation, and significant classroom events. The interviews, journal entries, and field notes provided contextual evidence supporting the quantitative findings.

2.6 Data Gathering Procedure

Data gathering was conducted through preparatory, instructional, and post-instructional activities. Before the intervention, Grade 9 Science topics were selected from the K to 12 Science Curriculum. Lesson plans incorporating Fishbone-Oriented Instruction were prepared and reviewed by the research adviser and Science education experts. Their recommendations were incorporated into the instructional materials. Permission to conduct the study was secured from the Schools Division Office and the school principal, while the Science teachers were informed about the research. The Attitude Toward Science Scale was pilot-tested among Grade 10 students from another school to establish its suitability. Before the intervention, the participants completed the instrument as a pretest to determine their initial attitudes toward Science. The two Grade 9 sections were subsequently taught through Fishbone-Oriented Instruction for eight weeks. Both sections followed the same schedule, lesson pacing, instructional time, content coverage, and Science topics. During each lesson, the teacher introduced the topic, after which students worked in small groups to identify causes, related factors, and relevant concepts using fishbone diagrams. The groups presented their outputs, while the teacher reviewed, synthesized, and enriched the discussion. Quizzes were administered to assess understanding, and homework activities were provided to reinforce learning. Students completed journal entries throughout the intervention, while the teacher-researcher recorded classroom observations through field notes. After the eight-week intervention, the students completed the same attitude instrument as a posttest. Individual interviews were then conducted, and the students' journals, field notes, and interview transcripts were compiled for qualitative analysis. A qualitative expert assisted in reviewing the thematic analysis.

2.7 Data Analysis Techniques

Quantitative attitude scores were encoded and analyzed using SPSS. Descriptive statistics were used to summarize the students' attitude levels before and after the intervention. The Wilcoxon Signed-Rank Test was employed because the pretest and posttest scores came from the same participants and did not satisfy the assumption of normality. Statistical significance was evaluated at the 0.05 level. An effect size expressed as r was calculated to determine the magnitude of the observed change. Values equal to or greater than 0.50 were interpreted as indicating a large effect. The qualitative data were analyzed using the six-phase thematic analysis framework proposed by Braun and Clarke (2006). The process involved familiarization with the data, initial coding, searching for themes, reviewing the themes, defining and naming them, and preparing the final account. Trustworthiness was established through triangulation of interview responses, journal entries, and field notes. Member checking was used to verify selected participant responses. An audit trail documenting the coding and theme-development process was reviewed by a qualitative expert to support dependability. Reflective notes were also maintained to enhance confirmability and minimize researcher bias.

2.8 Ethical Considerations

The study followed applicable ethical research guidelines. Students were informed about the study's purpose, procedures, voluntary nature, and confidentiality measures. Assent forms and informed-consent documents were provided before participation. Participants were informed that they could respond freely or withdraw from the study at any time without penalty. Identification codes were used to maintain anonymity, while collected data were handled securely and confidentially. The participants were treated with respect throughout the research process, and audio recording was conducted only with their consent.

3. Results and Discussion

3.1 Students' Attitude Levels Before and After Fishbone-Oriented Instruction

3.1.1 Pre-Intervention Attitude toward Science

The Attitude towards Science Scale developed by Shah & Mahmood (2011) and the categorization scheme adapted from Pratiwi et al. (2018) showed that all 68 students initially had unfavorable attitudes toward Science. Thirty-eight students, representing 55.9% of the participants, had negative attitudes, while 30 students, or 44.1%, had very negative attitudes. None demonstrated neutral, positive, or very positive attitudes based on the classifications adapted from Pratiwi (2018). Interview responses also revealed that students previously relied heavily on listening and memorization, experienced difficulty understanding Science concepts, and had limited opportunities for discussion and collaboration. The teacher's field notes similarly indicated that students were generally passive, rarely asked questions, and had minimal involvement in classroom activities. These findings indicate that the students' initial attitudes were associated with passive and teacher-centered learning experiences. Limited interaction, autonomy, and problem-solving opportunities may have reduced their motivation, confidence, and emotional connection to Science. Constructivist learning theory explains that meaningful understanding and favorable attitudes develop when learners actively construct knowledge through interaction and reflection (Piaget, 1970; Vygotsky, 1978). Motivation is likewise affected when students experience limited autonomy, relevance, and active involvement in learning activities (Pintrich and Schunk, 2002).

3.1.2 Post-Intervention Attitude toward Science

After the eight-week implementation of Fishbone-Oriented Instruction, all participants demonstrated favorable attitudes toward Science. Fifty-nine students, representing 86.8%, obtained very positive attitude ratings, while nine students, or 13.2%, obtained positive attitude ratings. No student remained in the neutral, negative, or very negative categories. Interview responses, journal entries, and field notes indicated that students became more participative, collaborative, prepared, and willing to share their ideas. They also reported that the strategy helped them understand lessons more deeply instead of merely memorizing information. The shift from entirely unfavorable to entirely favorable attitudes suggests that FOI improved students' interest, enjoyment, confidence, motivation, and perceived value of Science. Its visual structure allowed learners to break down problems and organize related causes, while group activities provided opportunities to exchange ideas and develop shared understanding. Istikomah (2017) found that structured visual tools such as the Fishbone Diagram improve critical thinking and engagement, while Latha and Merlin (2019) reported improvements in analytical thinking, motivation, and participation. The collaborative findings also reflect Vygotsky's (1978) emphasis on learning through social interaction and Papert's (1980) view that learners develop deeper understanding through active creation and reflection. The findings further support Shah and Mahmood's (2011) position that positive attitudes toward Science are strengthened by meaningful and supportive classroom experiences. Constructivist theorists such as Vygotsky (1978) and Bruner (1996) similarly explain that students develop more positive dispositions when they actively organize and construct knowledge. The visual organization provided by FOI may have increased conceptual clarity and engagement, consistent with Clary and Wandersee's (2013) findings. Positive attitudes are also associated with greater motivation and achievement in Science (Osborne et al., 2003).

3.2 Difference Between Pretest and Posttest Attitude Scores

The students obtained a pretest mean attitude score of 41.09, with a standard deviation of 3.13 and scores ranging from 36.70 to 55.00. After the intervention, the mean increased to 77.77, with a lower standard deviation of 2.42 and scores ranging from 72.50 to 82.50. The Wilcoxon Signed-Rank Test produced a Z-value of -7.172 and an asymptotic significance value of .000. Because the p-value was lower than the 0.05 level of significance, the null hypothesis was rejected. The posttest scores were therefore significantly higher than the pretest scores. The substantial increase in the mean score demonstrates that FOI meaningfully improved students' attitudes toward Science. The reduction in the standard deviation also indicates that students' post-intervention scores became more consistent, suggesting that the strategy supported learners with varying initial attitude levels. FOI functioned as both a visual scaffold and an active learning strategy by helping students organize ideas, clarify causal relationships, and participate in structured discussions.

The findings are consistent with Ishikawa-based instructional approaches that enable learners to organize information and examine relationships among ideas (Ishikawa, 1986, as cited by Gopinath, 2020). They also support Vygotsky's (1978) emphasis on guided learning and social mediation and Bruner's (1960) assertion that meaningful instructional tools can strengthen learners' dispositions. The results likewise reflect the affective domain of Bloom's Taxonomy, in which attitudes may be shaped through experiences that encourage learners to respond to, value, and internalize academic activities (Krathwohl, 2002). The active and visual characteristics of FOI are consistent with factors associated with improved attitudes toward Science (Osborne et al., 2003).

3.2 Students' Perceptions of Fishbone-Oriented Instruction

3.3.1 Visual Structuring and Connection of Ideas

Students perceived FOI as useful for visually arranging information and connecting related scientific ideas. They reported that the diagram helped them identify root causes, group similar factors, recognize patterns, and understand how different concepts contributed to a particular issue or outcome. This finding shows that visual structuring reduced the complexity of

Science topics by presenting information in an organized form. It is consistent with Clary & Wandersee (2010), who found that fishbone diagrams assist learners in visualizing complex relationships in Science. It also supports Istikomah et al. (2017), who reported that structured visual strategies improve students' critical thinking and engagement.

3.3.2 Understanding Cause-and-Effect Relationships

Students reported that FOI helped them understand how different causes were related to specific effects. They were able to categorize causes, distinguish human-induced and other contributing factors, and use the diagram to identify possible explanations and solutions to scientific problems. The findings suggest that FOI promoted analytical thinking by requiring students to examine relationships rather than memorize isolated information. Its cause-and-effect structure supported active knowledge construction, consistent with Constructivist Learning Theory, as discussed by Bruner (1996) and Fosnot (2013). The strategy allowed students to develop understanding by interpreting, organizing, and connecting information.

3.3.3 Enhanced Engagement, Interest, Collaboration, and Participation

Students described the activities as engaging, interactive, and participatory. They became more interested in the lessons, contributed during group discussions, prepared for presentations, responded to classmates' questions, and worked collaboratively to complete their diagrams. The teacher's observations confirmed that students became more participative and cooperative than they had been during previous lessons. These results indicate that FOI transformed students from passive recipients of information into active participants. Its collaborative nature allowed learners to exchange explanations, correct misunderstandings, and construct knowledge collectively. This finding resonates with Vygotsky's Sociocultural Learning Theory, which emphasizes that learning develops through social interaction, guidance, and shared meaning-making.

3.3.4 Valuing Idea Sharing and Student Expression

Students perceived FOI as an opportunity to contribute ideas, express their understanding, brainstorm with classmates, and reflect more deeply on Science topics. Group members were able to assume different roles, compare interpretations, and communicate their reasoning during classroom presentations. The findings demonstrate that FOI supported both cognitive and social dimensions of learning. Encouraging students to express and evaluate ideas strengthened their sense of involvement and ownership of the learning process. Overall, the qualitative evidence showed that FOI integrated visual organization, analytical reasoning, collaboration, and student expression, resulting in more meaningful and positive Science learning experiences.

4. Conclusion & Recommendations

The findings demonstrate that Fishbone-Oriented Instruction was effective in improving the cognitive, affective, and behavioral dimensions of students' Science learning. Before the intervention, the participants generally displayed negative to very negative attitudes toward Science, which were associated with passive participation, reliance on memorization, limited classroom interaction, and difficulty understanding scientific concepts. After eight weeks of Fishbone-Oriented Instruction, all students developed positive or very positive attitudes, indicating substantial improvement in their interest, confidence, motivation, and willingness to participate in Science activities. The strategy enabled students to visually organize information, identify and connect possible causes and effects, correct misconceptions, and analyze scientific problems more systematically. Its collaborative application also encouraged students to exchange ideas, ask questions, prepare for group presentations, and take greater responsibility for their learning. The interview responses, journal entries, and classroom observations supported the quantitative findings by showing that students perceived FOI as engaging, interactive, understandable, and helpful in promoting idea sharing and deeper reflection. Overall, Fishbone-Oriented Instruction provided a meaningful and equitable learning experience that strengthened students' conceptual understanding while fostering more favorable attitudes and active participation in Science.

Future studies should examine whether the positive changes in students' attitudes, engagement, and understanding are sustained beyond the immediate intervention period. Long-term investigation may determine whether continued exposure to Fishbone-Oriented Instruction produces lasting improvements in students' interest, confidence, motivation, and participation in Science. Further research may also explore the integration of FOI with other active learning strategies to determine how combined instructional approaches may support students' understanding and attitudes. Such studies should continue examining students' experiences and perceptions alongside quantitative outcomes to provide a more comprehensive explanation of how Fishbone-Oriented Instruction influences Science learning.

Compliance with ethical standards

The study complied with applicable institutional ethical standards, and the necessary permissions were obtained from the Schools Division Office and school authorities. Participation was voluntary, with informed consent and student assent secured before data collection. Participants were informed of their right to withdraw without penalty, while confidentiality

and anonymity were protected through coded identifiers and secure data handling. Audio recording was conducted only with consent. The author assumes responsibility for the originality and integrity of the work, acknowledges the contributions of the participants, school personnel, research adviser, and expert validators, declares no conflict of interest, and observes applicable copyright requirements.

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