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Enhancing scientific communication skills in junior high school pupils: A mixed methods investigation of engineering design process tools

Pramudya Dwi Aristya Putra[1], Sri Wahyuni[2], Nurul Fitriyah Sulaeman[3], Rifati Dina Handayani[4], Devi Yustika[5]

[1]*Faculty of Education, University of Jember, Indonesia, Corresponding author, pramudya.fkip@unej.ac.id, ORCID ID: 0000-0002-1166-8220*
[2]*Faculty of Education, University of Jember, Indonesia, ORCID ID: 0000-0002-0454-0640*
[3]*Faculty of Teacher Training and Education, Mulawarman University, Indonesia, ORCID ID: 0000-0001-5098-0615*
[4]*Faculty of Education, University of Jember, Indonesia ORCID ID: 0000-0001-5860-1202*
[5]*Faculty of Education, University of Jember, Indonesia, ORCID ID: 0009-0008-6181-1102*

ABSTRACT
Effective scientific communication is crucial for effective science education, as it allows for the sharing of ideas and research findings. This study investigates the impact of the Engineering Design Process (EDP) on pupils' scientific communication skills. A mixed-methods approach was used, combining both quantitative and qualitative data to assess the effectiveness of EDP tools in improving communication skills. The study involved 68 eighth-grade pupils, with 12 selected for in-depth observation to better understand the development of their communication abilities. Pre- and post-tests were conducted to measure improvement in scientific communication skills. Additionally, the Systematic Gravity (SG) method was applied to analyse the qualitative progression of these skills. The results showed that EDP tools positively influenced pupils' communication abilities, with a gradual shift towards more effective scientific communication (SG ++). These findings suggest that EDP tools can be an effective strategy for educators to enhance learners' problem-solving and communication skills. Further research with a larger sample size is recommended to confirm and expand these findings.

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Introduction

Communication skills are fundamental to the effective delivery of scientific concepts in science education (Karasheva et al., 2021). They play a crucial role in helping learners not only understand science but also engage with engineering practices. Engineering practice is implemented in science education for practical applications and fostering interdisciplinary learning (García-Carmona & Toma, 2024). The Next Generation Science Standards (NGSS) underscore the importance of communication as a key component in the learning process, enabling learners to articulate scientific ideas and present findings clearly and persuasively (NGSS, 2013). However, despite widespread recognition of their importance, research on how learners communicate scientific concepts remains underdeveloped because scientific communication skills manifest differently across learners at various academic levels (Kelp & Hubbard, 2021). For instance, early-stage learners typically focus on structured reporting and evidence-based claims, while graduate and doctoral students demonstrate advanced proficiency through peer-reviewed publications, methodological rigor, and the ability to tailor communications for both specialized and general audiences (Aslan, 2021; Fernández-Costales, 2023), particularly concerning how students connect their ideas to the integration of science and engineering practices (Kulgemeyer, 2018). Existing studies often focus on written communication, such as vocabulary use, data presentation, or formulating conclusions (Fatihah et al., 2022; Noviana et al., 2019). However, these studies often neglect broader aspects of communication, particularly in conveying complex scientific ideas effectively across various formats (Asfar et al., 2021). This gap in research limits our understanding of how learners use evidence to support their scientific claims and connect their learning to real-world scientific issues, especially within the realm of scientific ideas (Kagan et al., 2023; Kulgemeyer & Wittwer, 2023).

An essential component in fostering effective communication skills in science classrooms is the teaching approach. The interaction between everyday language and scientific language requires careful attention to ensure pupils can navigate both (Putra et al., 2024; Wahyuni & Ilham, 2024). A promising approach to fostering these skills is the implementation of the Engineering Design Process (EDP), which offers learners the opportunity to solve problems by exploring multiple potential solutions (Guzey & Ring-Whalen, 2018). This study addresses the gap in research by investigating the potential of EDP as a tool to enhance junior high school pupils in scientific communication skills (Xue et al. 2024). While previous studies have examined how EDP fosters critical and creative thinking (Levrini et al., 2021; Putra et al., 2023), its role in improving communication skills within the science classroom has been less explored (Eppler et al., 2021).

The novelty of this research lies in its focus on the iterative, problem-solving nature of EDP, which offers junior high school pupils opportunities to develop their communication skills while engaging in scientific and engineering practices. By integrating communication tasks within EDP, such as defining problem, collaborating with peers, and using evidence to support arguments (Anwar et al., 2022), this study proposes a learning approach to integrating scientific communication in a specific science topic. This perspective offers a more holistic understanding of how scientific communication can be developed as an integral part of the scientific process, particularly within the context of the Sustainable Development Goals (SDGs), rather than being viewed as a stand-alone skill set (Afkarina et al., 2024).

The study aims to investigate the integration of communication skills within the Engineering Design Process (EDP) framework, which emphasises iterative design as a means of enhancing learners' ability to effectively present their scientific ideas in specific science topic. Additionally, the study seeks to explore how these communication skills develop throughout the process. The research is guided by two central questions:

1) How does the integration of the EDP framework in the classroom influence the proficiency of junior high school pupils' scientific communication skills?

2) What is the developmental trajectory of junior high school pupils' scientific communication skills as they engage with the various stages of the EDP?

Theoretical Framework

Scientific communication is defined as the process of conveying technical or scientific information clearly and effectively, using valid evidence (Gregory et al., 2024; König et al., 2024). It involves not only the delivery of information and ideas but also the application of reasoning to ensure the audience's understanding (Borowiec, 2023). In the fields of science and engineering, scientific communication serves as a crucial mechanism for disseminating research findings and innovative ideas (NGSS, 2013). Kulgemeyer (2018) argued that the focus of scientific communication should align with specific topics and mastery within the context of science education. Effective scientific communication is not only about understanding scientific concepts but also about how these concepts are communicated to others using evidence-based reasoning (Shivni et al., 2021). Thus, the integration of communication skills with conceptual mastery is essential for fostering a comprehensive understanding of science and enhancing the ability to present research findings effectively.

However, despite the recognised importance of scientific communication, there remains a challenge in the exploration of specific domains that define and measure these skills. While various frameworks for scientific communication exist, many focus primarily on general competencies rather than reflecting proficiency across multiple aspects of developing skill levels in a particular area. For example, previous research has developed scales for measuring scientific communication, including dimensions such as awareness, enjoyment, interest, opinion formation, and understanding (Wu et al., 2019). Additionally, research in the field of scientific communication within education has evaluated on evaluating aspects such as clarity, factual accuracy, relatability, and purposeful targeting (Olesk et al., 2021). However, this framework does not include science concepts specifically in scientific communication. This study further explores the domain of scientific communication with a particular focus on mastering science concepts and integrating them into effective classroom learning approaches.

The domains to be explored in this study include the organisation of specific concepts, the demonstration of scientific phenomena, the use of scientific terminology, and the representation of evidence within the field of science (Afkarina et al., 2024; Yustika et al., 2023). Using these domains, this study will provide students understanding of how scientific communication can be developed and assessed with the specific context especially in science education (Kulgemeyer & Wittwer, 2023).

In the context of learning environments, scientific communication can be integrated with educational approaches that focus on facilitating students' ability to think iteratively and communicate effectively. One such approach that can be applied in the classroom is the Engineering Design Process (EDP). EDP allows learners to collaborate with peers, share ideas, and present their product to others (Lottero-perdue et al., 2015). The EDP is structured in stages that guide learners through a problem-solving process. These stages enable them to define the problem, learn relevant concepts, plan solutions, prototype, test, and evaluate their solutions (Guzey et al., 2019). Each stage of the EDP provides an opportunity to enhance their communication skills.

In the EDP, learners are faced with a real-world problem connected to scientific phenomena, requiring them to work collaboratively to identify the most effective solution (Sulaeman et al., 2021). In the define stage, they are expected to clearly articulate the problem they are addressing, which necessitates the use of evidence to communicate their understanding to the group. Next, during the learn stage, they take on roles within the group to gather information related to the problem, using scientific concepts to inform their research. In the plan stage, they must discuss their proposed solutions and the rationale behind their choices, justifying them with scientific evidence. Furthermore, in the try and test stages, they communicate their findings, including both successes and limitations, through clear, evidence-based communication. Finally, in the decide stage, they collaborate within their group to reach a consensus on their final solution. By integrating scientific communication into each stage of the EDP, they not only understand of scientific concepts but also develop the ability to present their ideas in a scientifically rigorous manner, using relevant concepts and topics (Yenice & Özden, 2022).

The focus topic of this study is on the Sustainable Development Goals (SDGs), which are widely recognized as a pivotal issue for students to comprehend, emphasizing the delicate balance between technology and the environment (Killian et al., 2019). However, teaching SDGs poses a significant challenge in the classroom, particularly within the science domain, as both pupils and teachers may find the concept unfamiliar (Clark et al., 2022). Overcoming this challenge necessitates innovative approaches to integrate SDGs effectively into the curriculum, fostering a holistic understanding of the intersection between science, technology, and sustainable development.

Methods

This research adopted a mixed-methods approach, combining both quantitative and qualitative methods, aligning with Creswell's recommendations (2012). The chosen methodology was the convergent parallel mixed-methods design, wherein two distinct sets of data were collected simultaneously and subsequently analysed independently using quantitative and qualitative analytical approaches (Dawadi et al., 2021). This approach provides a comprehensive understanding of the research questions, offering insights from both numerical data and qualitative observations (Alshehri, 2024), thereby enriching the overall exploration of the implementation of the EDP tool in the context of microplastics to enhance students' scientific communication skills.

In the quantitative phase, the implementation of the EDP tools was tested, and statistical analyses were employed to measure its impact on students' Scientific communication skills, particularly in science, within the experimental class in comparison to a control group. The study meticulously observed and analysed the distinctions in communication between the two classes, focusing on aspects such as comprehension, engagement, and overall effectiveness of the STEM-microplastic topic integration.

Complementing the quantitative phase, the qualitative aspect encompassed in-depth interviews and content analysis. These methods were chosen to capture rich, contextual insights from participants, offering a deeper understanding of their perceptions and experiences with the microplastic-case curriculum. Together, these mixed methods provide a comprehensive exploration of the multifaceted aspects of the research question.

Context of Study

The inception of the EDP tool, integrated with the contextual case and centred around the critical theme of microplastics, marked the initiation of an 8-week learning process aligned with the SDG number 14 (see table 1). This goal aimed to instil in pupils a commitment to preserving underwater environments. Originally conceived as a tool to enhance communication skills in science, the EDP tool underwent a meticulous validation process. Three experts evaluated its content, ensuring its relevance to the enhancement of students' scientific communication skills.

Furthermore, the structure of EDP tool was meticulously crafted, following the systematic approach of the engineering design process, as outlined by (Sulaeman et al., 2021). The sequence adhered to a thoughtful progression: define, learn, plan, try, test and decide. This deliberate framework was implemented to provide pupils with a comprehensive and structured learning experience.

Table 1

The 8-week learning process in EDP and SDGs program in science class

Week	Duration	Activities	Goals
1	80 min	Introduction of EDP and SDGs Programme	Assess pupils' initial understanding of the EDP stages and the SDGs program through a pre-test.
2	80 Min	Defining Problem	Students define the problem related to SDGs number 14 (Life below water), addressing water pollution caused by microplastics (example in appendix).
3	80 Min	Learning Scientific Concepts of the Ocean Environment	Pupils define the problem related to SDGs number 14 (Life below water), addressing water pollution caused by microplastics.
4	80 Min	Planning a Solution	Pupils plan solutions to address the defined problem by designing equipment based on given criteria.
5	80 Min	Try	Pupils construct prototypes and test their designs to filter microplastics from water.

6	80 Min	Test	Pupils conduct tests, compare results with peers, and evaluate the effectiveness of their designs.
7	80 Min	Decide	Pupils present solutions to the audience, receive feedback, and engage in the redesign process.
8	40 Min	Evaluation of the program	Assess the impact of the EDP and SDGs programme on pupils' understanding and scientific communication skills through a post-test.

Participants

The participants in this research were categorised into two groups based on the employed methods. The first group underwent quantitative research, comprising N = 68 junior high school pupils from one school where the location near a coastal area, with a female-to-male student ratio of 1:1. All participants were in the 8th grade, distributed into two separate classes representing the control and experimental groups. In the experimental group, the STEM approach was applied, utilising EDP tool focused on the preservation of the underwater environment. Conversely, the control group received conventional classroom instruction with a broader emphasis on environmental topics. Conventional learning emphasizes a textbook-centred approach where knowledge is transmitted primarily through teacher-led. Furthermore, qualitative methods were exclusively implemented in the experimental class, involving only 12 specific pupils, based on group that an equal distribution of female and male students. The students' selection was also considering the abilities of medium, low, and high in their learning outcomes. These pupils focused on the discussion to solve the problem based on the EDP tools about microplastic project.

Data Collection

All participants in this research took part in both a pre-test and a post-test, which aimed to assess their scientific communication skills. The pre-test was administered at the beginning, prior to the participants engaging in an experimental and control class, while the post-test was conducted at the end of the programme. The questions in both the pre-test and post-test covered four dimensions of scientific communication skills, as shown in table 2.

Table 2

The dimension of the scientific communication skills measured

Dimension	Criteria
Dim – 1	Organising topics based on the condition of SDGs issues.
Dim – 2	Demonstrating skills in conveying examples of scientific phenomena.
Dim – 3	Using scientific terms in the relevant field of science.
Dim – 4	Presenting representative forms of scientific evidence findings.

In addition, the qualitative aspect of the research focused on how pupils addressed problems presented by their science teacher using a digital book developed for the study. Their discussions were recorded and transcribed to generate data for analysis. The triangulation data collecting, towards the end of the programme, participants in the qualitative research were interviewed to gather their responses regarding the use of the digital book and how they approached problem-solving based on their ideas.

Data Analysis

The quantitative research results underwent analysis using SPSS, encompassing an examination the post-test in the end of the programme. The *t*-test was administered to investigate disparities in scientific communication skills between the experiment and control classes. The progress in scientific communication was evaluated via N-gain based on the differentiation of pre-test and post-test results, classifying improvements as low, medium or high.

For qualitative data, a code book was formulated and organised based on the driven-theory code outlined in the appendix. Transcripts from discussions were categorised by domains. The findings were then elucidated using semantic gravity (Lee & Wan, 2022) to chart the degree of improvement in each domain of pupils' scientific communication skills on a weekly basis. The levels of semantic gravity are described in table 3.

Table 3

Definition of semantic gravity based on the domain

Domain	Level Range	Criteria
Dom – 1	SG++ to SG --	SG++: Clearly and comprehensively articulate the problem's topic and its impact. SG+: Accurately address both the problem's topic and its impact, though the coverage may be incomplete. SG-: Inaccurately and incompletely state both the problem's topic and its impact. SG--: The prepared topics remain overly abstract.
Dom – 2	SG++ to SG --	SG++: Clearly and precisely explain the causes and consequences of the natural phenomenon of global warming. SG+: Specifically explain the causes and consequences of the natural phenomenon of global warming, but with some lack of precision. SG-: Explain the causes and consequences of global warming, but with less specificity and precision. SG--: Unable to articulate the causes and consequences of the natural phenomenon of global warming.
Dom – 3	SG++ to SG --	SG++: Proficiently utilise all four types of scientific language terms (e.g., microplastic, PET, waste treatment, and life ocean)., SG+: Effectively use three types of scientific language terms. SG-: Use only 1-2 types of scientific language terms. SG--: Use everyday language.
Dom – 4	SG++ to SG --	SG++: Incorporate accurate scientific concepts supporting appropriate design choices. SG+: Mention scientific concepts supporting design choices, but some may be inaccurately applied. SG-: There is no mention of scientific concepts supporting the design choices. SG--: Students mention scientific concepts, but they do not effectively support appropriate design choices.

Note. This criteria was modified from lee & Wan (2022)

Findings

The primary research question in this study centres on the implementation of Engineering Design Process (EDP) tools and their influence on the scientific communication skills of students. Prior to the *t*-test the collected data underwent evaluation for normality and homogeneity, with detailed findings presented in Table 4. This table is expected to provide information on the distribution of data and the normal distribution of variances, offering crucial insights into the statistical aspects of the research. Additionally, Table 5 likely contains a description of the homogeneity test, further elucidating the equality of variances across groups.

Table 4

The normality data of variance of post-test based on the scientific communication skills

Domain	Class	Statistic	df (n-1)	Sig.
Dom – 1	Experiment	.952	34	.064
	Control	.957	34	.613
Dom – 2	Experiment	.929	34	.138
	Control	.975	34	.198
Dom – 3	Experiment	.929	34	.124
	Control	.975	34	.056
Dom – 4	Experiment	.935	34	.626
	Control	.954	34	.066

Table 5

The description of the homogeny test between the experiment and control class

Domain	Levene statistic	df (n-1)	Sig.
Dom – 1	5.571	66	.078
Dom – 2	5.043	66	.067
Dom – 3	4.936	66	.083
Dom – 4	5.088	66	.086

The results of the normality and homogeneity tests, indicating significance values above 0.05, suggest that the collected data is both normally distributed and homogenous between the experiment class and the control class. These findings validate the appropriateness of proceeding with further analysis. The impact of implementing Engineering Design Process (EDP) tools could now be systematically investigated using a 2X2 ANOVA facilitating a nuanced comparison between the experiment class and the control class. This statistical approach aims to discern any significant differences in outcomes, providing valuable insights into the effectiveness of the EDP tool implementation in enhancing scientific communication skills among pupils in the experiment class compared to the control class.

Table 6

Independent t sample Test

Domain	Max Score	Class	N	X	Sd	t	P
Dom – 1	100	Experiment	34	78.53	4.48	0.021*	0.05
		Control	34	55.47	3.43		
Dom – 2	100	Experiment	34	76,42	4.60	0.000*	0.05
		Control	34	66.75	7.52		
Dom – 3	100	Experiment	34	75,82	4.32	0.000*	0.05
		Control	34	64.74	4.25		
Dom – 4	100	Experiment	34	78,50	4.45	0.000*	0.05
		Control	34	70.24	7.56		

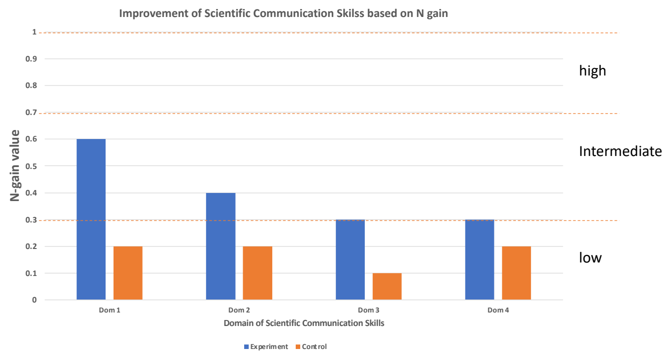
Note. *Significant p value < (α) 0.05

Table 6 elucidates a comparative scrutiny of mean scores derived from post-tests administered to both the experimental and control classes. Utilizing a predetermined significance level (α) of 0.05, the *t*-test analysis, centring on scientific communication skills, unveiled a statistically significant result ($p < 0.05$). This discovery signifies a conspicuous differentiation in scientific communication skills between the control and experimental classes. The assimilation of EDP tool encompassing SDGs-related issues manifested a positive influence on the communication skills of the pupils. Notably, the mean scores reveal that the experimental class outperformed the control class in each domain of scientific communication skills.

The improvement of each domain of scientific communication could be described in figure 1. The figure 1 presents a diagram to evaluate the improvement in scientific communication skills of pupils in this study. The colour-code described to different the achievement based on the three-development stages in low, intermediate, and high. The improvement in the scientific communication skills of pupils is depicted, with the experimental class exhibiting a higher improvement compared to the control class. The values representing the improvement in the experimental class fall within an intermediate level, ranging from 0.3 to 0.7. In contrast, the control class shows improvement at a lower level.

Figure 1

Comparison between the experimental and control class groups regarding the improvement of students' communication skills



In the experimental class, Domain 1 exhibited the most substantial improvement compared to other domains in scientific communication skills. This indicates that the pupils successfully organised microplastic topic within the context of SDGs. Conversely, Domain 4 displayed lower improvement, suggesting that they encountered challenges in providing scientific evidence to substantiate their ideas using various representations such as tables, figures, graphs and textual information.

In the control class, the domain showing the lowest improvement was Domain 3, where pupils faced difficulties in using scientific terminology accurately. Furthermore, it is notable that the improvements between Domain 1, Domain 2, and Domain 4 were equal in magnitude.

The qualitative investigation focused on the active involvement of two groups in collaborative problem-solving discussions within a classroom setting. Figure 2 serves as a visual representation of the Semantic Gravity Wave Model, providing clarification on the communication processes among group members. This model contributes valuable insights into the development and evolution of scientific communication skills domains throughout the diverse activities conducted in the classroom.

Figure 2

The Semantic Gravity Wave Model applied to the scientific communication skills of pupils

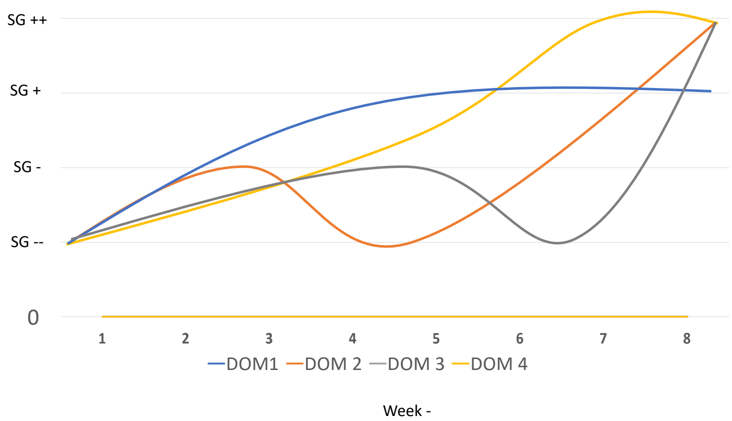


Figure 2 presents the Semantic Gravity Wave Model, offering a visual representation of the evolution of communication processes among pupilss during problem-solving discussions in the experimental classroom. This model serves as a trajectory, capturing the dynamics and intricacies of communication development, providing a framework to understand the progression of scientific communication skills. Initially, pupils faced challenges in providing detailed descriptions of scientific phenomena, particularly in domains 1, 2, 3, and 4 (SG--), with explanations being abstract. However, over time, especially in domains 1, 2, 3, and 4, they transitioned towards explaining scientific phenomena with appropriate evidence, indicating a positive trend towards SG++. This shift reflects the improvement and refinement of their scientific communication skills throughout the week.

In Domain 1, pupils start at SG-- and progress toward SG++` Initially, they find it challenging to grasp the Sustainable Development Goals (SDGs) issue. They perceive that discussions about global warming rarely take place in their daily lives. For instance, when students engage in conversations in week 1 (students define the problem stage) with friends unfamiliar with global warming, they may express their experiences like this (all the translation had been validated Deviandri et al., 2023).

[A10]: I've discussed global warming with my friend. During that conversation, I encountered some confusing materials related to physics after my studies. Seeking clarification from friends and delving deeper into the subject through additional studies helped me understand better. However, I haven't explored discussions about ocean pollution or other SDGs issues yet (SG --).

In domain 2, pupils encountered the challenge of developing explanations for scientific phenomena in the world, particularly in expressing these explanations scientifically in their daily lives. The EDP tool played a crucial role in fostering connections between real-world phenomena and scientific concepts. The conversation among them serves as an illustration of their struggle in explaining a world phenomenon related to the ocean environment. This interaction highlights the progress achieved in narrowing the gap between everyday observations and a more scientific understanding through the application of the EDP tool. This specific example occurred on the fourth day when they found it challenging to explain the concept of a tsunami.

Vignette 1

[A1]: Can you name three examples of natural phenomena commonly found around beaches and oceans?

[A2]: Well, when people are near the coast or ocean, one common question is, "Is there a tsunami around here?"

[A1]: True, if there's a beach nearby, the possibility of a tsunami exists.

[A2]: What causes tsunamis? Is it because the sea water rises onto the land? (SG --]

It is fascinating to see how pupils are actively incorporating scientific terminology into their discussions while using the EDP tool. The guided nature of the EDP tool seems to play a pivotal role in shaping the students' ability to employ scientific language. Their use of terms like "magnetic field," "iron powder," and "microplastic" reflects not only an understanding of scientific concepts but also an aptitude for effectively communicating their ideas within a scientific context. The dialogue showcases their thoughtful consideration of the sequence in implementing solutions, indicating a structured and scientific approach fostered by the EDP tool. Vignette 3 showed the pupils interaction to use the scientific terminology (Domain – 3)

Vignette 3

[A1]: Our design involves the use of a magnetic field, so we need to collect iron powder, oil and a magnet.

[A2]: Should we start with the magnet first or introduce the iron powder into the water?

[A6]: We experimented with adding oil to gather microplastics. Once the microplastics clump together, we can sprinkle in the iron powder and then use a magnet to create a magnetic field to lift them (SG ++)

It is evident from Domain 4 that pupils are not only adept at communicating their ideas but also versatile in choosing diverse forms of expression and providing supporting evidence. The use of both text and visual representation, such as pictures, to convey the scientific phenomena during the equipment design phase showcases their ability to employ multiple mediums for effective communication. [A4]'s contribution in proposing a solution through text and presentation further emphasizes the students' proficiency in articulating their ideas with clarity and detail. This multifaceted approach to communication aligns with the complexity of scientific problem-solving and demonstrates their capacity to convey intricate concepts through various means.

[A4]: For the experiment aimed at removing microplastics from the sea, we acquired six tools and materials. Initially, we utilised sticks, plastic, iron powder, cloth, and oil. In the first trial, we employed a stick by directly submerging it into the water. We observed that microplastics adhered to the popsicle sticks. However, we demonstrated that this method was relatively ineffective, as only a small amount of microplastics was removed. Therefore, it proved to be inefficient and time-consuming [SG-].

Discussion

Question Research 1: How does the integration of the EDP framework in the classroom influence the proficiency of junior high school pupils’ scientific communication skills?

This research focused on investigating learners' scientific communication using a EDP tool that integrate with the SDGs topic, specifically addressing goal number 14 in SDGs. The evidence indicates that the EDP project tool has a positive impact on pupils' scientific communication skills at this level. In the experimental class, they actively engaged in discussions to solve case-problem given in the tool, facilitating communication of their ideas within their groups. On the other hand, the control class followed conventional approach, where the material is solely delivered by the teacher, and students work on their worksheets in groups.

The EDP tool serves as a systematic guide for learners to methodically define and solve real-world problems (Fan et al., 2020). This structured approach encourages them to gather evidence, explore solutions, and delve into relevant scientific concepts and phenomena. Throughout the EDP process, they articulate and share their problem-solving ideas, aligning the content with the challenges presented in the tool. Importantly, they organize their ideas to connect with the SDGs, ensuring that their problem-solving goals contribute to sustaining human life in a healthy environment. This integration of problem-solving, scientific concepts, and alignment with SDGs creates a comprehensive and meaningful learning experience (AlAli et al., 2023).

The EDP tool is like a guide that helps learners solve real-world problems. In this case, the challenge is about dealing with pollution caused by small bits of plastic in water. Pupils use the tool to talk about how using too much plastic in their daily lives can harm the environment, especially water. They collect evidence, like facts and observations, to explain the situation scientifically. The evidence they find helps them connect scientific ideas, like why plastic is hard to break down. This process not only improves their problem-solving skills but also helps them better understand the science behind environmental issues related to plastic pollution. Notably, the experimental class exhibits higher pupil hands-on activity using EDP than the control class, emphasising the effectiveness of the EDP tool in guiding pupils to explore and communicate their ideas systematically. This aligns with previous research highlighting the importance of fostering pupil activity in the classroom to encourage idea development and structured communication (Sarıoğlu et al., 2023).

In the experimental class, pupils showed a heightened awareness of using scientific terminology, especially when explaining phenomena related to the environment. During discussions, they fluently incorporated scientific terms, reflecting a proficiency likely developed through guided instructional approaches. This aligns with research by Sharon & Baram-Tsabari (2020), highlighting the role of teaching methodologies in facilitating adept usage of scientific language. The EDP tool, through its integration of environmental issues and relevant materials, prompts learners to articulate their design work with a language influenced by their learning experiences within the tool's scientific context. This dynamic interaction showcases how instructional tools can shape learners' linguistic expressions in scientific discourse.

Scientific communication skills showed notable improvement in the experimental class compared to the control class, particularly in domain-1. Initially, pupils in the experimental class were unfamiliar with SDGs terms and struggled to connect them with scientific concepts. For instance, during an early interview, one pupil [A10] expressed unfamiliarity with SDGs and faced challenges in linking it to scientific ideas. However, by the end of the sessions and following the steps of the EDP tool, they were adeptly employing SDGs terminology, especially in the context of preserving the underwater environment. Consequently, the gain in domain-1 was the most significant. Pupils in the experimental class demonstrated enhanced fluency in discussing topics related to the EDP project.

Domains 3 and 4 displayed lower N-gain scores, indicating challenges in mastery of scientific knowledge and its application to real-world concepts. In these domains, pupils were tasked with explaining their design work to solve problems, which proved to be more challenging. They tended to focus more on describing how their designs addressed the problem rather than delving into the underlying scientific knowledge embedded in their designs. This aligns with previous research highlighting that transitioning from scientific problems to design solutions can lead to multiple possible solutions, but it also poses a risk if not balanced with a well-organised instructional approach (Bozkurt Altan & Tan, 2021). Without proper guidance, pupils may prioritise the design aspect over mastering the scientific concepts (Putra et al., 2023).

Research Question 2: What is the developmental trajectory of junior high school pupils' scientific communication skills as they engage with the various stages of the EDP?

The development of pupils' communication skills follows a gradual improvement in their ability to articulate ideas. This progression is characterised by a shift from abstract concepts to more tangible, visually representable comprehension over time. Through the EDP tool, they engage in a step-by-step process, beginning with defining solutions and progressing through the design stages until they arrive at a final resolution for the given problem. This engineering design approach allows them to navigate from simpler to more complex thinking, fostering future-oriented thought processes (Levrini et al., 2021). Moreover, the EDP tool enables learners to communicate their findings using multiple modes, facilitating clear understanding for their peers. The incorporation of evidence in their communication is a crucial factor that influences the audience's acceptance of their ideas (Johnson et al., 2020) .

The observations of Domains 3 and 4 reveal underperformances in learners' mastery of scientific communication skills could this also relate to the mother tongue? A key challenge in scientific communication lies in their proficiency within these domains. In Domain 3, they struggle not only with understanding the appropriate use of scientific terminology but also with applying these terms in specific contexts. For instance, many are unfamiliar with the term "microplastic" and mistakenly believe it refers to a type of plastic that can be manually removed from water to solve pollution problems. This misconception highlights the need to shift their thinking towards a more scientific understanding of terms, which involves integration scientific concepts with real-world applications (Canfield et al., 2020). Furthermore, exposing learners to specific scientific topics during their learning stages enables them to better understand and familiarize themselves with the terminology and issues at hand. The EDP framework tool in this study helps clarify the steps they should follow, providing a structured approach to advance their understanding and application of scientific concepts (Rees Lewis et al., 2023).

In Domain 4, pupils face difficulties in presenting their results using multiple forms of representation. For instance, while they may effectively visualise steps for removing microplastics from water through images, they struggle to integrate text and visuals coherently. This challenge underscores the need to combine textual and visual elements to convey their ideas effectively. Previous research has also highlighted that using multiple representations to communicate scientific concepts is a significant challenge in scientific communication (Holford et al., 2023). In this domain, learners are tasked with collecting evidence and visualising their ideas using appropriate imagery to minimise misconceptions. The EDP framework supports this by allowing learners to present their results through various formats, helping ensure that the audience understands the presenter's intent.

Conclusion and Implications

The integration of the EDP tool in the science classroom has demonstrated a positive and significant impact on enhancing junior high school pupils' scientific communication skills. The improvement in scientific knowledge was found to be moderate in the experimental class and lower in the control class. The study specifically focused on evaluating science concepts rather than general communication skills. The trajectory of scientific communication in the experimental class showed a gradual shift from [SG --] to [SG ++] over the course of meetings. This progression indicates that pupils engaging with the EDP tool in the classroom were able to develop their scientific communication skills, transitioning from abstract to more representable comprehension understanding.

This study underscores the pivotal role of a well-structured instructional approach in elevating school learners' scientific communication skills. Progressing from simple to complex concepts, educators guide learners in seamlessly integrating evidence with scientific knowledge, fostering a holistic understanding. Effective communication, underpinned by evidence-backed reasoning, becomes a cornerstone of problem-solving. Moreover, this research emphasises the profound impact of connecting environmental teachings with the SDGs. By intertwining scientific concepts with future-oriented SDGs, educators contribute to shaping environmentally conscious individuals equipped to tackle global challenges like climate change. The findings affirm that cultivating robust scientific communication skills is not merely about solving problems but empowering learners to articulate, justify, and contribute to a sustainable future.

This study acknowledges certain limitations in its scope, particularly the exclusive focus on SDGs Goal 14. This choice was influenced by the geographical context of the pupils, primarily residing near coastal areas. Additionally, the implementation of the EDP tool was confined to a single junior high school, necessitating broader application across diverse schools and educational levels for more comprehensive insights. Future research endeavours could replicate this study across varied populations to substantiate the efficacy of the EDP tool in enhancing scientific communication skills. Expanding the study's reach can contribute to a more nuanced understanding of the tool's effectiveness in different contexts.

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