



Biology communication skills: Engaging innovations with 'two stay, two stray

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ABSTRACT

One of the essential skills needed by prospective elementary education teachers is scientific communication. The issue raised is the low level of communication skills among students in the context of relevant biological issues, which can hinder their engagement in biology science discussions and evidence-based decision-making. This study aims to analyze the scientific communication skills of prospective science teachers in biological science concepts. The research adopts a descriptive approach in its methodology. The research process was conducted through direct observation of learning activities taking place in the classroom. The population in this study consists of students from the elementary teacher education program at a public university in Ambon City, with a sample size of 80 students. The results indicate that the implementation of the Two Stay, Two Stray (TSTS) approach significantly improves students' communication skills. The average communication skills score increased by 71.41%, falling into the good category. These findings suggest that this collaborative approach is effective in enhancing students' understanding of biological issues and their ability to communicate effectively. This study recommends the implementation of active learning methods such as TSTS in science education to facilitate the development of scientific literacy and students' communication skills.

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INTRODUCTION

In the era of globalization and advancements in information technology, skills have become increasingly important as a foundation for society to face various complex, multidimensional challenges such as climate change, global pandemics, social inequality, and intergroup conflicts. Both developed and developing countries are beginning to realize that the ability of society to understand, evaluate, and critically use scientific information is crucial for successfully managing social and environmental issues (Wu et al., 2018). Developed countries, such as China, the USA, the UK, and others, value the benefits of scientific advancements because they have embraced the body of scientific knowledge, including biology. This is because they consider science, particularly biology, to be very important for the social and economic growth of a country (Kambaila et al., 2019). For example, in 2020, the world experienced a shock due to COVID-19, which prompted scientists to think hard about finding solutions in the form of vaccines to address the issue. Therefore, the school curriculum can support this effort by preparing quality scientists for the future. The difficulties students face in learning biology have been studied by various researchers worldwide. This dream is a hope for all countries; however, the situation on the ground still shows unsatisfactory results. This can be seen from students still struggling with their learning. Many topics in biology are considered difficult, prompting researchers to investigate why students experience these difficulties and how to address them. There are many reasons why students struggle to learn biological concepts (Mendez et al., 2024; Zha et al., 2025). Study results show that in science tests, when the average answers per subject were examined, the percentage of correct answers was 42.6% for physics, 46.4% for chemistry, and 38.1% for biology, making biology the subject with the lowest percentage for these students (Telli et al., 2009). The lowest percentage of questions answered correctly has raised concerns among many teachers, students, and researchers in Turkey, all of whom wonder why students struggle to answer biology questions correctly on national exams (Çimer, 2012).

The gap is widening due to the different communication skills required for scientists to communicate with peers and non-scientists. Most scientists learn communication skills through cultural transmission. Undergraduate biology students learn to develop communication skills to better explain scientific concepts and recent developments in science to non-scientists (Goldina & Weeks, 2014). Integrating communication skills with biology education in schools is crucial for developing students who are not only able to understand biological concepts but also able to apply them in everyday life and social issues. A study from Université Laval, Canada, found that science communication is generally female, with a career-oriented motivation pattern, and most view science communication skills as an asset for careers in communication, science, or health (Daoust-Boisvert, 2022). In the context of biology education, this can be done through project-based learning, where students are encouraged to learn about environmental or public health issues (Cameron et al., 2015). For example, they might study the impact of pollution on local ecosystems or investigate the causes of diseases. Through these projects, students learn more than just biological concepts; they also develop their communication skills as they express their thoughts to classmates, friends, or family members. Additionally, classroom discussions about social issues related to biology, such as climate change, species conservation, or bioethics, can enhance students' civic scientific literacy. In these discussions, students are invited to express their opinions, listen to others' perspectives, and argue based on scientific data. Scientific communication skills are essential for graduates with a science degree (Zhang et al., 2024). Interestingly, it has been reported that high-achieving students perform better in lower-level classes focused on content when communication skills and scientific processes are taught alongside content, and that combining these skills helps reinforce competencies (Faber et al., 2024). The curriculum is designed based on scientific literature that involves students in many active learning activities to develop various types of scientific communication skills. For graduates starting careers in science, high-quality science communication skills are crucial, as clear communication is necessary to disseminate findings, form effective collaborations, and secure funding (Kuehne et al., 2014). Thus, written and oral communication skills are the most sought-after qualities from job applicants in biology departments at academic institutions (Fleet et al., 2006). Furthermore, students developing science communication skills can help them understand scientific concepts, the scientific process, and the skills to engage with science after they graduate, regardless of whether they pursue a career related to science (Shivni et al., 2021).

Communication is also a key element in promoting team development, as it helps to build trust, motivation, cohesion, and understanding among team members, which translates into increased productivity and achievement of goals. By developing the communication skills of trainees through interactive retreat activities, we hope they can cultivate competencies that will contribute to the success

of team collaboration in the future (Schmidt et al., 2023). The idea that skills can be built through cooperative collaboration is not new, nor is it unfamiliar to educators. In the early 20th century, John Dewey proposed that the role of educators is to prepare students to be democratic citizens by engaging them in real-world problem-solving through collaboration and imagination (Ye & Shih, 2021). One way to achieve this goal is by implementing the appropriate learning model. The basic activities that students engage in during the learning process include speaking, listening, writing, reading, conducting experiments, and observing. It is hoped that students' interest in the classroom will increase by making them the focal point of the learning process. The teacher's role is to motivate students to participate in various learning activities. With high motivation, it is expected that students' interest in learning will grow, thereby improving their science learning outcomes (Mujasam et al., 2018). Cooperative learning will encourage students to solve the problems presented and discuss them with their peers. In this way, teachers can involve more capable students to assist their less capable classmates. Cooperative learning can enhance student engagement and learning outcomes (Bećirović et al., 2022) as well as communication skills (Ismirawati et al., 2024). When completing group tasks, each student collaborates and helps one another to understand the learning material. The teaching and learning process is a crucial element that influences the achievement of learning objectives. For more than 40 years since then, cooperative learning has been tested and proven effective as a learning method in various studies (Ghorbani & Nezamoshari'e, 2012; Essien, 2015). Among group study approaches, cooperative learning refers to practices where students form small study groups or teams to complete structured tasks toward shared learning goals through cooperation. Cooperative learning has the following features: positive interdependence, face-to-face promotive interaction, individual and group accountability, interpersonal skills and small group processing. This impactful practice is related to social interdependence theory (Zhou & Lewis, 2021). The Two Stay, Two Stray (TSTS) model provides students with the opportunity to share results and information with other groups through inter-group visits.

The TSTS cooperative learning model is highly effective in creating an active, efficient, and enjoyable learning environment, as every student has the responsibility to actively participate in the learning process, support each other, and share information in problem-solving. Thus, learning becomes more meaningful and can motivate students to achieve success. TSTS aims for students to collaborate, take responsibility, help each other achieve success, and develop good social skills (Reinita & El Fitri, 2019). TSTS model positively impacts communication skills in biology by fostering peer interaction, which encourages students to articulate their thoughts clearly. It promotes active listening, allowing students to engage with diverse viewpoints, and enhances critical thinking as they evaluate each other's ideas (Dewi et al., 2016). Regular participation builds confidence in expressing ideas, while teamwork develops interpersonal skills essential for effective communication. In an enthusiastic science class, several gifted students showed a particular interest in various communication skills. They enjoyed activities involving public speaking, debating, and discussing. However, it was evident that the levels of skill acquisition varied, and there were sometimes differences between male and female students. In this way, more skilled students could assist their peers who were still in the learning process, creating a collaborative and supportive atmosphere. These activities were not only enjoyable for the students, with role-playing games and debates being held, but also provided opportunities for them to reinforce the skills they had already mastered while learning new ones. Through this approach, educators successfully balanced the acquisition of new skills with the reinforcement of existing ones. Gifted students felt motivated and engaged, learning from one another in a dynamic and enjoyable environment. With the right support, they not only developed their communication skills but also built confidence and social skills that would be valuable in the future (Alfarah, 2013). Additionally, TSTS encourages reflection on communication experiences, leading to improved strategies. Overall, TSTS not only deepens understanding of biological concepts but also equips students with vital communication skills for academic and professional success (Likita et al., 2020). This study aims to analyze the scientific communication skills of prospective science education teachers in biological science concepts.

METHODS

Research Design

The type of this research is quantitative descriptive with a survey method, aimed at determining the level of biology students' communication skills in the basic science concepts course according to the sequence of material in Table 1. The research process was conducted through direct observation of the

learning activities taking place in the classroom. It is important to note that this observation was carried out without any intervention from the researcher, meaning there were no additions, deletions, changes, or manipulations to the observed learning process. In accordance with general procedures in research, data collection was conducted without using tests, but rather through observation and documentation. The observations in this study were carried out by analyzing the implementation of learning using a non-participatory method, where the researcher was not directly involved in the ongoing learning activities (Iacono et al., 2009). Meanwhile, the documentation method was applied by systematically following the focus and issues of the research (Ahmed, 2024). The types of documentation used included images, audio, and video relevant to the context of the research.

Population and Samples

In this study, the population of focus consists of all students enrolled in the Elementary School Teacher Education Program (PGSD) who are taking the Basic Concepts of Natural Science (IPA) course in their second semester. This population includes students from various cohorts who are participating in the course at the same university, providing a comprehensive overview of their understanding and attitudes toward the fundamental concepts of natural science. The selection of this population is highly strategic, considering that PGSD students are future teachers who will teach natural science at the elementary school level. Therefore, a deep understanding of the basic concepts of natural science is crucial, as it will influence the quality of instruction they provide to students in the future. In the context of education, teachers with a strong understanding of the material they teach tend to be more capable of conveying information clearly and effectively, and they can inspire students to become more interested in science. To obtain representative data, the research sample will be drawn from two classes consisting of a total of 80 students, namely classes A (40 students) and B (40 students). The sampling technique used is nonprobability sampling with a saturated sample approach, ensuring that all available students participated in the study. The sampling process will take into account various factors, including the diversity of students' backgrounds and their experiences in studying natural science. By selecting these two classes, it is hoped that a sufficient variation in the data can be obtained, allowing the analysis to reflect a broader condition of the PGSD student population.

Instrument

The research activities took place for five months and focused on the following topics.

Table 1

Arrangement of Learning Material

Topic	Subtopics	Material Code
Plants and Their Environment	a. Parts of plants and their functions b. Seeds c. Vegetative reproduction d. Plant habitats	F01
Animals and Their Environment	a. Animal classification	F02
Human Anatomy and Physiology	a. Skeletal and muscular systems b. Nervous system c. Transportation and respiratory systems d. Digestive system e. Nutrition	F03

The instruments used in this study have been validated to measure students' communication skills in Taiwan. These instruments consist of twelve indicators that cover four main aspects: expression, evaluation, response, and negotiation (Chang et al., 2011; Soh et al., 2012). Table 1 presents the details of the instruments used in this research.

Table 2

Instrument of Students' Communication Skills

Aspect	Indicator
Expression	1. Able to describe data with different ways 2. Able to show the relation between data 3. Able to understand the meaning between data in different ways 4. Able to see the content or data through different ways or perspective

Aspect	Indicator
Evaluation	5. Able to show the truth of different data or opinion
	6. Able to differentiate facts and conclusion
	7. Able to clarify data or statement with unclear statement
Response	8. Able to ensure statement from friends
	9. Able to respond unclear statement from friends
	10. Able to separate different ideas from friends or themselves
Negotiation	11. Able to revise their opinion based on friends' input
	12. Able to conclude the discussion from group discussion

The procedures in this study involve observation and analysis of communication skills indicators during the learning process, starting from the steps of learning activities that include the stages of apperception or evaluation. The objects observed are teachers and students, with a particular focus on student activities and engagement in the learning process related to the use of communication skills based on the indicators from the assessment instrument. Subsequently, data is collected, and the indicators in the learning process are grouped. These data groups are then analyzed descriptively and quantitatively. The performance of these indicators is calculated as a percentage to determine the potential performance of communication skills for each indicator, which is then adjusted to 100% based on the established criteria. The percentage is calculated by summing all occurrences of potential in each indicator, then dividing the result by the total amount of potential present. After that, the result of the division is multiplied by 100% to obtain the percentage value. The categories of communicative competence potentials are defined based on scoring percentages. A score ranging from 81 to 100 is classified as "Very Good," indicating a high level of competence. Scores between 61 and 80 fall into the "Good" category, reflecting a solid understanding and ability in communication. An average score, which is between 41 and 60, signifies a moderate level of competence. Scores that range from 21 to 40 are considered "Low," suggesting that there is significant room for improvement. Finally, scores from 0 to 20 are categorized as "Very Low," indicating a critical need for development in communicative skills.

Procedure

The cooperative learning activity using the TSTS model was conducted over seven sessions. The implementation of the TSTS model follows six learning stages formulated by Arends (1997): Present goals and set, Present information, organize students into learning teams, assist teamwork and study, Test over materials, and Provide recognition. Overall, the learning activities were aimed at enhancing students' biological communication skills. One distinctive feature that sets the two-stay-two-stray cooperative learning model apart from others is its group formation strategy, which includes the following steps: 1) Students typically work in groups of four, and the teacher assigns a task involving questions that they need to discuss and answer; 2) Once they finish, two members from each group leave to meet with another group; 3) The two remaining members in the original group are responsible for sharing their work and information with their guests; 4) The two guests are required to visit all groups. After their visits, they return to their original groups.; 5) Upon returning, both the visiting students and those who hosted guests compare and discuss their findings.

Data Analysis Techniques

The data sorting process involves separating the collected data into relevant and irrelevant information. This step is crucial to ensure that the analysis focuses on high-quality data, resulting in more accurate and reliable outcomes. After sorting, the data is then specified according to the established communication skills rubric. This rubric serves as a guide to categorize and assess communication skills based on specific criteria. In this way, the researcher can organize the data more structurally, facilitating the analysis and interpretation of results. This specification process also helps maintain objectivity and consistency in the assessment. The results of the analysis of scientific communication skills are then represented through twelve indicators encompassing four main aspects: expression, evaluation, response, and negotiation. The expression aspect refers to an individual's ability to convey ideas and information clearly and effectively. Evaluation relates to the ability to assess information and arguments from others. Response includes how individuals provide feedback to the communication received, while negotiation involves the ability to reach an agreement in communication situations involving multiple parties. By using these indicators, the researcher can provide a more comprehensive picture of the scientific communication skills possessed by the individuals studied. Overall, this analytical technique aims to provide a deep understanding of communication skills with a

systematic and structured approach, allowing for more effective evaluation and measurement of communication skills.

RESULTS AND DISCUSSION

Table 4 presents comprehensive data regarding students' achievements across various communication skills indicators, providing a detailed overview of their performance in this essential area. This table is systematically divided into four main aspects: Expression, Evaluation, Response, and Negotiation, with each aspect encompassing several specific indicators that reflect distinct dimensions of students' communicative abilities. Each indicator serves to illustrate the students' competencies in diverse facets of communication, while also indicating the percentage of achievement that reveals how effectively they meet the established criteria for success. The Expression aspect is particularly focused on assessing students' capacity to articulate their thoughts and describe data from multiple perspectives, which is vital for effective communication. In contrast, the Evaluation aspect emphasizes students' skills in critically assessing the accuracy of information, enabling them to differentiate between factual data and personal opinions, a key component of analytical thinking. The Response aspect is designed to evaluate students' abilities to engage with their peers by responding thoughtfully to statements and clarifying any ambiguities in communication, fostering an environment of collaborative dialogue. Lastly, the Negotiation aspect assesses students' proficiency in revising their opinions based on constructive feedback from others and effectively summarizing group discussions, which is essential for collaborative problem-solving and consensus-building. The percentage of achievement displayed in the last column of the table provides a clear and quantifiable picture of each indicator's mastery level as demonstrated by the students. This data is not only valuable for measuring individual performance but is also crucial for identifying both strengths and areas that require improvement in students' communication skills. These skills are fundamental for successful learning and social interaction within an academic environment, highlighting the importance of continuous development in these areas for overall student growth and engagement.

Table 4
Student Achievement for Each Communication Skills Indicator

Aspect	Indicator	Achievement Percentage (%)
Expression	1. Able to describe data with different ways	75%
	2. Able to show the relation between data	65%
	3. Able to understand the meaning between data in different ways	77%
	4. Able to see the content or data through different ways or perspective	68%
Evaluation	5. Able to show the truth of different data or opinion	70%
	6. Able to differentiate facts and conclusion	
	7. Able to clarify data or statement with unclear statement	82% 68%
Response	8. Able to ensure statement from friends	75%
	9. Able to respond unclear statement from friends	67%
	10. Able to separate different ideas from friends or themselves	65%
Negotiation	11. Able to revise their opinion based on friends' input	78%
	12. Able to conclude the discussion from group discussion	67%

Based on the analysis results from Table 1 of the twelve indicators, the average is 71.41%, which falls into the good category. This study aligns with the research conducted Laslo & Hartmann (2023) on the topic of cell biology, where the average score for poster presentations in both classes was 91%, indicating an excellent achievement of the learning objectives for scientific communication during the summative assessment stage. Additionally, research Jauhari (2025) shows that students' communication skills regarding the concept of the human skeleton demonstrate good performance. Other studies support the same notion that nursing students' skills in using therapeutic communication techniques are classified as moderate to high (Mercan & Mersin, 2025). The TSTS cooperative model is a teaching method designed to enhance interaction and collaboration among students, particularly in

the context of biology learning. In this model, students are divided into small groups, allowing them to engage in in-depth discussions about predetermined topics. The learning process begins with group formation, where each student has the opportunity to share their knowledge and ideas. During this initial discussion, students ask questions, explain, and listen to one another, which is a crucial step in developing communication skills. After the initial discussion, two students from each group will move to another group, while two others remain in their original group. The students who move bring information and understanding from their original group to share with the new group. This movement is not merely a change of seats but also an opportunity for students to broaden their perspectives. They can explain what has been discussed in their original group, encouraging them to convey information clearly and structurally. In the new group, the moving students will share the knowledge they brought and listen to new ideas from their peers. This creates a dynamic dialogue where students can exchange views and deepen their understanding of biology material. Students who remain in their original group also have the chance to hear new perspectives, enriching their discussions. After the sharing session is complete, students return to their original groups. Here, they can discuss what they have learned from the other groups, integrate new information into their understanding, and reflect on the learning process they have undergone. Students' communication skills in biology learning can be categorized as good through the use of this model for several reasons. First, this model encourages active interaction. Students are not just passive listeners; they are directly involved in the learning process by speaking, arguing, and discussing ideas. This interaction is vital in developing effective communication skills. Furthermore, students learn to listen well. The ability to listen to explanations from their peers is an important part of effective communication. By listening, they can understand others' viewpoints and respond appropriately.

Furthermore, this model aids students in language development. Group discussions provide them with the opportunity to use biological terms and concepts with greater confidence. They learn how to explain complex ideas in a way that others can understand. Additionally, this model teaches students about cooperation and collaboration. They learn how to interact with others, appreciate differing opinions, and resolve disagreements constructively. Students' self-confidence also increases through this model. When they speak in front of their peers and share information, they feel more assured in their communication abilities. This confidence is essential for the further development of their communication skills. Moreover, students receive feedback from their peers, which helps them evaluate and improve their communication skills. This reflection process is crucial for personal and academic growth. Overall, TSTS provides an excellent opportunity for students to develop their communication skills within the context of biology learning. By encouraging active interaction, collaboration, and the exchange of ideas, this model creates a supportive and positive learning environment. Students not only learn about biological material but also hone skills that will be useful in various aspects of their lives. Good communication skills will assist them not only in academic contexts but also in social and professional interactions in the future.

Cooperative teaching is student-oriented, where they work in diverse groups to achieve common goals. This method involves collaboration between pairs or small groups of students to reach those objectives. TSTS facilitates collaboration to maximize individual knowledge through interaction with other group members. In this process, students shift from a passive position to an active role in the learning process, leading to improved performance (Slavin, 2014). Furthermore, cooperative teaching reinforces the psychological aspects of students, as a cooperative atmosphere reduces competition, eliminates dominating criticism and rejection, and helps students develop a positive self-view and feel accepted by their group peers. Cooperative learning also contributes to the democratization and socialization of students, as they actively engage in decision-making through discussions and collaborative tasks. This method frees students from passive listening, strengthens initiative, and fosters intrinsic motivation. Students are encouraged to practice critical thinking skills and are prompted to develop self-awareness and self-critique (Buchs et al., 2017) since they are often asked to compare themselves with others and contribute to the group. In this context, competition and egocentrism are minimized, while values such as altruism, mutual respect, solidarity, and personal and collective responsibility are nurtured. Additionally, students are taught techniques and methods of working effectively. Ultimately, students who were initially disinterested become inspired to participate in activities, manage their own time, and are indirectly guided to improve themselves. The cooperative teaching method also helps teachers create a student- and group-centered learning environment, enabling students to achieve optimal academic, affective, and social-interpersonal development (Jolliffe

& Snaith, 2017).

Teachers provide learning incentives to all students and design group activities where they can express questions, views, and disagreements, as well as discuss ideas, critique, explain, and make decisions collaboratively. Additionally, teachers arrange the classroom in such a way that students consider one another, take responsibility, and learn to listen, appreciate, and help each other, regardless of gender, nationality, or academic achievement. By implementing cooperative learning techniques, teachers can harness students' energy, channel it into learning activities, and help them develop core skills to solve complex problems (Sharan, 2015; Duran et al., 2019). Cooperative teaching grants responsibility and authority to students, allowing them to work independently on assigned projects. Consequently, students have the freedom to determine how they complete tasks, even if they make mistakes, and they are accountable for the outcomes they achieve. Other research findings report a very different scenario, indicating performance disparities, where fourth and sixth-semester students exhibited poor performance across all aspects of nonverbal communication skills assessment. Observation data suggest that prospective biology teachers possess low verbal and nonverbal communication skills. This low level of communication ability may be attributed to a lack of variety in the models and techniques applied in the classroom, which are ineffective in training students to ask and answer questions. Observations indicate that students struggle to provide deeper explanations, connect information to everyday issues, express their thoughts and perspectives, question existing solutions, and comprehend the material being taught. They also face challenges in delivering conclusions and organizing discussion topics in a structured manner. This is due to a lack of conceptual knowledge and critical thinking skills among students. Furthermore, their engagement in building knowledge and understanding independently is minimal, as the learning process is dominated by repetitive lecture methods (Amin et al., 2022).

One aspect that can explain the poor communication skills of students is their misunderstanding of biological concepts (Borowiec, 2023). In this study, students appeared afraid to answer the lecturer's questions due to their lack of mastery of the material (Eklund & Isotalus, 2024). Additionally, mistakes in choosing the right sentences, a lack of knowledge about the subject matter, low self-confidence, anxiety, and a lack of fluency when expressing opinions in class also contribute to the challenges faced by the participants (Le et al., 2018). The communication process in this context encourages students to become proficient communicators by training them in effective communication methods. Students are initially trained to communicate in small groups, specifically with their partners. Communication skills can be enhanced through practice and training. Effective communication involves clearly expressing opinions as well as accepting others' viewpoints, and Nonviolent Communication (NVC) integrates these aspects. Nonviolent Communication, also known as compassionate communication, is a conversational model created by Marshall Rosenberg, inspired by the values of Mahatma Gandhi and the principles of Carl Rogers' therapy. This model consists of two main elements: honestly expressing feelings and listening empathetically. It is a technique rooted in compassion for others, which also encourages introspection and helps build relationships with others (Yang & Kim, 2022). The achievement of students in communication skills for each learning material can be illustrated in Figure 1.

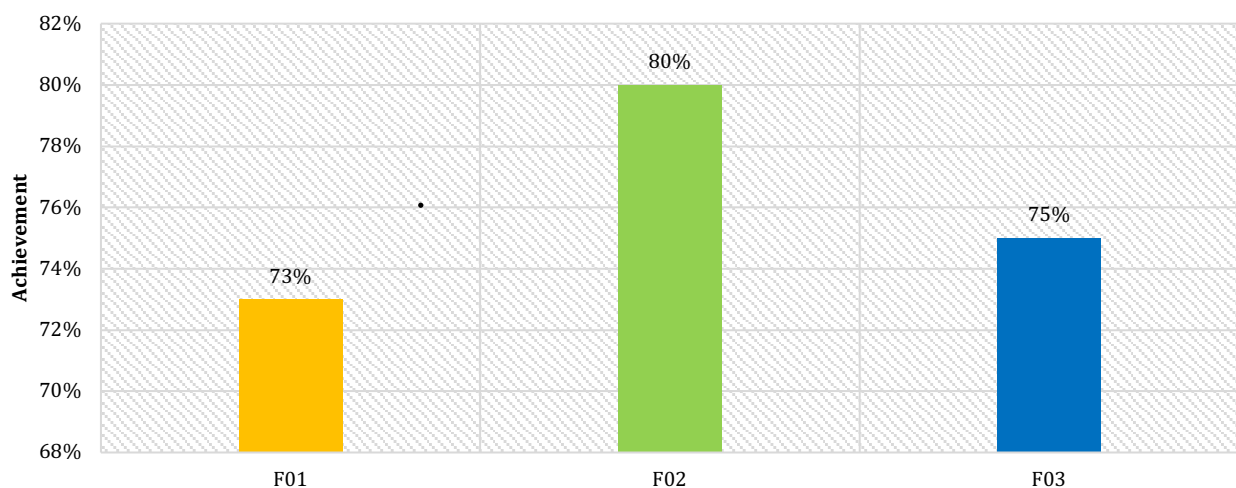


Figure 1. Student Achievement in Communication Skills for Each Learning Material

First, for the topic of Plants and Their Environment, which has the lowest achievement (73%), there may be several underlying reasons. This topic often contains complex concepts, such as the plant life cycle, photosynthesis processes, and ecosystem interactions. If the teaching is not sufficiently interactive or does not connect theory with practice, students may struggle to understand and integrate the information. Additionally, if students lack practical experience or direct observation of plants in their environment, this can diminish their understanding of the material. Despite the implementation of the TSTS strategy, the Plants/Environment category has shown unsatisfactory performance. This can be attributed to low student engagement, the complexity of the material requiring in-depth understanding, and imbalanced group dynamics. Additionally, inappropriate assessment methods, lack of resources, and ineffective instructor facilitation also contribute to the issue. External factors such as student stress and the absence of constructive feedback during the learning process can further exacerbate the situation. To improve performance, it is necessary to analyze group compositions and adopt teaching strategies that provide better support. On the other hand, for the topic of Animals and Their Environment, which has a higher achievement (80%), students may be more familiar with animals and their daily surroundings. This topic is often easier to comprehend because many students already have a foundational knowledge of animals from personal experiences or prior education. Furthermore, if the teaching involves more practical examples and field activities, this can enhance students' understanding and engagement. Meanwhile, for the topic of Human Anatomy and Physiology, which has an achievement of 75%, although students may be interested in this subject, the complexity of the human body systems and the interactions among them can pose challenges. This material requires a deep understanding of the structure and function of the body, and if the teaching is not sufficiently thorough or does not provide a practical context, students may find it difficult to connect theory with practice. However, a strong interest in health and the human body may encourage students to put in more effort to understand this material. Overall, the variation in achievement reflects differences in the complexity of the material, students' prior experiences, and the teaching methods employed. To improve achievement in all these areas, it is essential to use more interactive teaching approaches, leverage practical experiences, and connect the material to students' everyday lives. In this way, it is hoped that students' understanding of fundamental science concepts can improve overall.

It is important to note that TSTS is a student-centered and group-centered teaching method that provides greater independence and motivation for students to learn autonomously without intervention from the teacher. According to this teaching practice, teachers actively engage students in the learning process, which fosters higher cognitive, metacognitive, and emotional functions. This method not only aligns with broader contemporary pedagogical and didactic principles aimed at stimulating student interest, nurturing their social skills and relationships, developing their self-perception, and creating independent and fulfilled personalities, but it also aligns with the primary goals of the curriculum in these countries, which are fully in accordance with their educational policies and societal needs (Markoglou, 2022). Collaboration among students in the classroom allows individuals from diverse backgrounds to combine their skills to achieve the goals set by the teacher. Collaboration, problem-solving, conflict resolution, and teamwork are essential life skills. However, there are still questions regarding the appropriate ways to group students. For instance, it remains unclear whether students should be grouped based on ability, biological sex, interests, age, intelligence, and so on. Additionally, there is no certainty about whether students should be grouped homogeneously or heterogeneously based on their achievements in cooperative learning (Wyman & Watson, 2020).

This curriculum not only develops students' skills and self-efficacy in scientific communication but also engages them with course content and stimulates their research interest (Laslo & Hartmann, 2023). This not only enhances their understanding of biological material but also trains the communication and critical thinking skills that are essential in modern society. Overall, the integration of civic scientific literacy and communication skills in biology learning in the classroom enriches students' learning experiences and prepares them to become active and informed citizens. By understanding and being able to communicate about relevant biological issues, students will be better equipped to face the challenges that society currently faces. The results of the study indicate that the philosophy of biology education in our classroom is not to teach students "everything they need to know," but rather to teach them how to acquire knowledge efficiently and effectively in the future. To achieve this goal, we designed a one-semester course that teaches biological concepts and communication skills to students, loosely following the principles of constructivism (Troy et al., 2022). Therefore, higher education, as a training ground for future teachers, increasingly focuses on equipping

students with the necessary communication skills for professional conversations across various domains. Although teachers require communicative knowledge and subject-specific content for discussions on biological topics, specialized training in biological communication is rarely conducted (Meuleners et al., 2024).

CONCLUSION

This study comprehensively concludes that the implementation of the TSTS approach significantly enhances students' communication skills in biology science learning. The results indicate that students engaged in this collaborative method are better able to understand relevant biological issues and convey information more effectively. The average skill score increased to 71.41%, which is categorized as good. Therefore, this underscores the importance of using active learning approaches in science education. This not only provides a deeper understanding of the material but also prepares students to engage in public discussions and evidence-based decision-making, which are crucial in modern society. However, this study has several limitations. First, the sample size used is relatively small, involving only two classes at one school, which may limit the generalizability of the results to a broader population. This limitation could affect the external validity of the findings. Additionally, the study was conducted over just one semester, which may not be sufficient to observe the long-term impact of this approach on students' communication skills. Other factors, such as student motivation and support from teachers, were also not fully explored in this research, which could influence the outcomes. In terms of novelty, this research contributes to the existing body of knowledge by demonstrating the effectiveness of the TSTS approach specifically in the context of biology education, an area that has not been extensively studied in relation to communication skills enhancement. The findings provide empirical evidence that supports the integration of collaborative learning methods in science curricula, highlighting their potential role in fostering essential skills that are vital in today's society. Based on these findings and limitations, future research is recommended to conduct studies with larger and more diverse samples, as well as over longer periods to evaluate the sustainability of improvements in scientific literacy and communication skills. Research in various contexts, such as schools with different socioeconomic backgrounds, could also provide more comprehensive insights. Furthermore, additional studies could explore the effects of similar approaches in other disciplines, such as physics or chemistry, and at different educational levels, including secondary and higher education. Thus, it is hoped that this will provide broader insights into the effectiveness of active learning methods in enhancing student competencies across various fields. Finally, it is important to develop training for teachers in implementing active learning approaches like TSTS, so they are better prepared to effectively apply these methods. This will help create a more dynamic and interactive learning environment, which in turn can enhance overall student learning outcomes.

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