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STUDENTS' COLLABORATIVE PERFORMANCE THROUGH STEM TOPIC "LED CARD – LIGHT IT UP" FOR 8TH GRADE

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ABSTRACT

STEM education is a highly useful environment for improving students' collaborative competence by engaging them in hands-on, problem-based learning. However, in many countries, including Vietnam, there is little integration of STEM topics into natural science curricula. To address this gap, this study analyzes the design and implementation of a STEM lesson titled "LED Card – LIGHT IT UP" for 8th-graders to develop collaborative competence and deepen students' understanding of power sources and simple circuits. The study employed a quasi-experimental design with 21 students participating in three sessions, each lasting 45 minutes. Students worked in small groups and engaged in various collaborative activities: Numbered Heads Together, Brainstorming, Placemat, Gallery Walk, and XYZ. All group interactions during these activities were observed and video-recorded. The collected data were then qualitatively analyzed based on predefined collaboration criteria, including role assignment, idea exchange, feedback provision, and joint problem-solving, to assess each group's level of collaboration. The results revealed that four out of five groups consistently demonstrated effective collaboration, particularly during the reporting and design review sessions, despite facing challenges in online coordination. The integrated STEM lesson effectively enhanced students' collaborative competence while deepening their understanding of fundamental electrical concepts. The results also highlighted some limitations, such as student distractions and unequal contributions among members, indicating the need for improvements in techniques and teacher guidance methods to enhance the effectiveness of group activities in STEM topics. The novelty of this study lies in its innovative synthesis of established collaborative teaching techniques within a STEM framework, providing a promising approach for enhancing secondary education.

Keywords: STEM education; collaborative competence; teaching techniques

INTRODUCTION

Education is a fundamental pillar of the Sustainable Development Goals (SDGs), which emphasize the importance of inclusive, high-quality education and lifelong learning (United, 2019). In the process of learning, collaboration plays a vital role in problem-solving and knowledge development, as evidenced by its impact on communication, collective decision-making, conflict resolution, and dynamic leadership (Kelley et al., 2023). According to Johnson and Johnson (2009), collaborative environments enhance group interaction by facilitating material sharing, discussions, and mutual support. Felder and Brent (2007) describe collaboration as a team-based approach designed to maximize learning and foster satisfaction within a high-performing group work environment. Whether through group discussions or debates where students argue, refute, and validate claims through experiments, collaborative learning enhances

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argumentation skills and deepens conceptual understanding (Murdani et al., 2023). Furthermore, collaborative learning promotes autonomy, self-direction, verbal communication, and effective interdependence among group members while fostering positive student interactions (Meijer et al., 2020; Yang, 2023 Jurkowski et al., 2024). In such settings, students work in small groups to enhance both their own learning and that of their peers (Master et al., 2017; Wieselmann et al., 2019). Social interaction within collaborative learning positively influences group performance and knowledge construction (Järvelä et al., 2008; Reeves & Gomm, 2015; Rogat & Linnenbrink-Garcia, 2011). Moreover, the collaborative process exposes learners to multiple perspectives on the same issue, an aspect that is difficult to achieve when working individually (Sun et al., 2020). In the context of middle school, where students are developing more complex social skills and relationships, fostering collaboration skills can lead to better group dynamics, increased empathy, and improved conflict resolution abilities (Wentzel et al., 2014; Jurkowski et al., 2024). Collaboration benefits learning in multiple ways. For instance, stronger students help weaker peers by explaining and clarifying content, bridging knowledge gaps (Berisha & Vula, 2024). Additionally, students are more likely to procrastinate on assignments when working alone. Moreover, in collaborative settings, they recognize that their contributions impact others, which motivates them to stay engaged and complete tasks on time (Moges, 2019). Collaborative learning has also been shown to reduce students' misconceptions in physics (Haryono et al., 2024). Therefore, an essential aspect of cooperative learning is that students must work together to achieve learning objectives, which increases interaction between students and teachers (Abramczyk & Jurkowski, 2020).

Numerous studies have shown that STEM activities enhance not only the quality of the learning process but also learning outcomes and students' soft skills (Nugroho et al., 2019; Wang et al., 2022; Permanasari et al., 2024), including collaboration (Latip et al., 2020; Owens & Hite, 2020; Wiyono et al., 2022; Kurniahtunnisa et al., 2023). Rooted in the theory of group dynamics and collaborative learning, STEM activities are designed to engage students in structured group collaboration. Through formal collaborative learning, students interact, discuss, and work together toward a shared meaningful goal (Bulu & Tanggur, 2021; Micari & Pazos, 2021; Ngoc et al., 2024). The STEM lesson format serves as the primary approach for implementing STEM education in schools, which is typically integrated into formal science lessons and classroom activities. In Vietnam, the 2018 General Education Program underscores the importance of STEM education in fostering students' competencies and personal attributes through learning tasks that encourage teamwork, proactiveness, and independent problem-solving (Vietnam Ministry of Education and Training, 2018).

Previous studies have identified two key challenges affecting the integration of cooperative learning practices in the classroom: organizing collaborative activities and assessing student learning (Hämäläinen & Vähäsantanen, 2011; Chiriac & Granstrom, 2012). Ghavifekr (2020) examined the impact of collaborative learning on social interaction skills and revealed that 86% of students preferred group work, 92% reported improved communication, and 89% recognized stronger team spirit, underscoring its role in fostering interpersonal and problem-solving abilities. Similarly, Gillies (2023) found that collaborative learning enhances students' academic performance and actively engages them in the learning process. The study highlights how working in groups fosters scientific thinking, improves problem-solving skills, and deepens understanding through discussion and peer interaction, with teachers playing a crucial role in facilitating meaningful collaboration. Another study by Jurkowski et al. (2024) investigated a lesson-integrated training program for transactive communication involving 594 ninth-grade students in Germany. The training enhanced students' collaborative skills and transactive statements but had no significant impact on knowledge acquisition or motivation for group work. Dewi et al. (2021) conducted a quasi-experimental study with 31 Indonesian chemistry education students to examine the effects of ethnoscience-based contextual collaborative learning on scientific literacy. Using pre- and post-tests, the study found improvements in students' scientific content knowledge, process skills, and attitudes, with gains categorized as moderate. These findings underscore how collaborative learning, when integrated with cultural and real-world contexts, enhances students' ability to apply scientific concepts in daily life and fosters a deeper understanding of science. However, Abramczyk and Jurkowski (2020) found that while teachers recognize the benefits of cooperative learning for students' academic and social development, they struggle with its effective implementation. This finding is supported by a survey of 1,495 Polish language teachers, which revealed that despite their positive perceptions, a lack of practical knowledge hinders the frequent use of cooperative learning, emphasizing the need for further training and support. Moreover, teachers often face challenges in monitoring student behavior, managing time, providing materials, and assigning group roles (Gillies & Boyle, 2010). Prinsen et al. (2008) also noted that maintaining the quality of group discussions is a persistent issue for both primary and secondary students. This challenge can sometimes lead to imbalances, where low-achieving students become passive and contribute less to the group (Webb, 2009; Salonen & Savander-Ranne, 2015).

Another issue is that summative assessments of group work often fail to provide opportunities for individual evaluation (Sridharan & Boud, 2019). Additionally, students have expressed dissatisfaction with group tasks, as they are not designed to ensure that each student's contribution is fairly assessed (Glenn, 2009). In Vietnam, Ha et al. (2020) investigated collaborative competence in schools. Their research indicates that while Vietnamese students possess basic collaborative skills, they face significant challenges when engaging in more complex tasks that require advanced communication, conflict resolution, and leadership abilities. The study also highlights how teachers in Vietnam sometimes struggle with resource constraints, which hinders the effective implementation of collaborative learning strategies.

Research by Lien et al. (2019) resulted in a model for collaborative learning activities in STEM education at public schools to develop students' collaborative competence. This model has provided initial insights for researchers, educators, and administrators in planning and organizing collaborative learning activities, as studies on this topic remain limited. However, investigations of comprehensive STEM lessons specifically designed to enhance students' collaborative competence are still lacking. Grounded in the theoretical foundations of collaborative learning, this study seeks to address the challenges identified in previous research by integrating multiple teaching techniques to design and implement a STEM collaborative learning lesson for 8th-grade students. The objective is to observe and assess the development of students' collaborative competence through practical experimentation.

METHODS

This study adopted a quasi-experimental design to explore students' collaborative performance in a STEM lesson. The lesson was designed in alignment with the "Energy and Transformation" content strand of the 2018 General Education Program for Natural Science in Vietnam. This strand covers fundamental concepts such as simple electrical circuit diagrams, conductors and insulators, current flow direction, power source identification, and the construction of an electrical circuit to control the switching mechanism of a light on a card for "Women's day" using basic tools. According to Directive 3089 on STEM education implementation in secondary schools, the STEM lesson follows a structured process consisting of five main activities: (1) Defining the Learning Task, (2) Researching Background Knowledge, (3) Designing Solution Options, (4) Manufacturing the Product, and (5) Presenting, Discussing, and Adjusting (Vietnam Ministry of Education and Training, 2018). To enhance collaboration, an additional group formation phase was incorporated in Activity 1, which allowed students to identify each member's strengths and weaknesses and assign roles accordingly. The teaching process is explicitly illustrated in Figure 1. In addition, the following instructional tasks were employed throughout the lesson to develop students' collaborative competence:

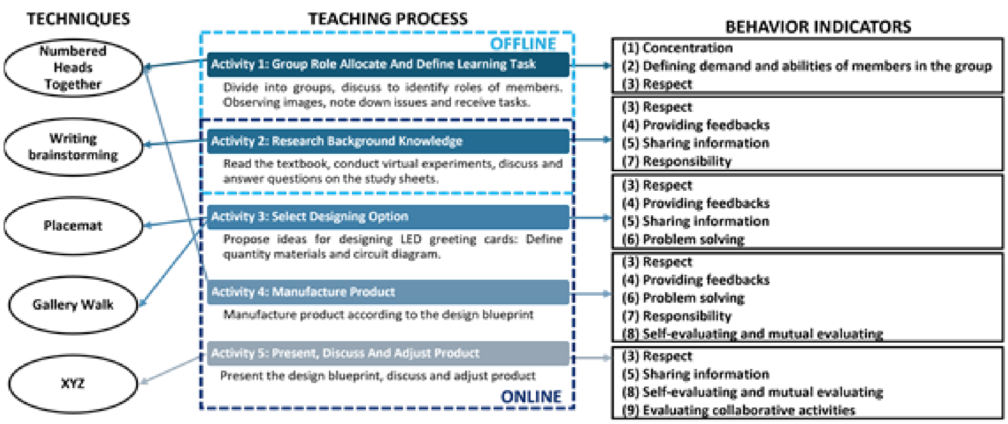

Figure 1. Teaching Techniques in Project LIGHT IT UP

Numbered Heads Together: In this activity, each group member is assigned a number. The entire group collaborates to discuss and find an answer to a question posed by the teacher. The teacher then randomly selects a group and a number. The student with the corresponding number is required to respond or present the group's discussion. This task is introduced in Activity 1 to help students become familiar with cooperative learning and to recognize their own competencies and those of their peers. It is also implemented in Activity 2 and Activity 4 to foster group discussion, active listening, and constructive feedback. Additionally, it leverages students' prior knowledge, enabling them to collaboratively apply their ideas to create the LED card product.

Written Brainstorming: In this method of brainstorming, students first write down their ideas individually before sharing them with the group. After collecting individual responses, the group reviews the ideas and selects the most appropriate solution for the group secretary to present. This technique is used in Activity 2 to promote individual responsibility and active information sharing. After learning about power sources, electrical currents, conductors, and insulators, students work together to select appropriate materials for making the LED card.

Placemat: Group members sit around a table and individually write their opinions on a large A0-sized sheet of paper. This activity is used in Activity 3, where students individually propose a design for the LED card that best fits the specified requirements. Each student presents their design idea in their designated section of the "placemat." Students are then given five minutes each to present their design ideas to their group members. Afterward, the group collaborates to select and finalize their design plan.

Gallery Walk: In Activity 3, after completing their design plans, groups participate in a gallery walk to receive peer feedback. Each student group sets up an exhibition to showcase their designs. Then the entire class walks around the exhibition, providing comments and suggestions on the work of other groups. This activity allows them to recognize the strengths of other teams and make adjustments to improve their own designs.

XYZ: In this activity, X refers to the number of group members; Y indicates the number of ideas each member must contribute; and Z is the amount of time (in minutes) allocated for group members to present or write down their opinions. Group members take turns sharing their ideas in a structured sequence. After one round of sharing, the group summarizes the ideas, evaluates them collectively, and discusses necessary adjustments. This activity is conducted at the end of the lesson to encourage students to reflect on their strengths and weaknesses, evaluate each group member's contribution, and assess the group's overall performance in the product creation process.

In accordance with the research plan, a quasi-experiment comprising three 45-minute lessons was conducted. During the experiment, in-person learning was temporarily suspended due to a new wave of COVID-19. The experiment involved only 21 (11 female and 10 male) 8th-grade students in Ho Chi Minh City and took place from February to early March 2022. As a result, the experiment was divided into two phases, with some adjustments aimed at continuing to foster students' collaborative competence. Phase 1 (offline) included Activity 1 and the first half of Activity 2, while Phase 2 (online) was conducted synchronously via Microsoft Teams with the remaining activities. The research team implemented a STEM lesson on the theme "LED Card – LIGHT IT UP" under the scientific topic "Energy and Transformation." The students self-organized into five collaborative groups, each consisting of four to five members.

This study employs both qualitative and quantitative research methods. In the qualitative study, observation and video recording were used to capture and analyze student activities. Meanwhile, the quantitative study consisted of an assessment tool to measure the extent of students' improvement in collaborative skills over the duration of the lesson (Herro et al., 2017; Nemiro, 2020). Herro et al. (2017) developed an assessment tool for evaluating student collaboration in STEAM education, called Co-Measure. This tool includes five main components: (1) Peer Interaction, (2) Positive Communication, (3) Inquiry Rich/Multiple Paths, (4) Authentic Approach and Tasks, and (5) Transdisciplinary Thinking. Each component is rated at three levels: "Needs Work," "Acceptable," and "Proficient" (Herro et al., 2017). Nemiro (2020) studied collaborative behavior and developed a rubric for evaluating communication and collaboration competence. This rubric assesses seven behavioral indicators: (1) Focus, (2) Effort, (3) Communication, (4) Problem-Solving, (5) Participation in Problem-Solving, (6) Attitude, and (7) Responsibility, all of which are scored on a scale from 0 (Not Performed) to 4 (Exemplary) (Nemiro, 2020). Both the Co-Measure tool and the rubric are reliable and well-suited for assessing students' collaborative behaviors. The Co-Measure tool places greater emphasis on problem-solving aspects. Because it describes behavioral indicators related to problem-solving and interdisciplinary approaches, this tool is particularly effective for assessing and continuously monitoring students' collaboration, both in class and at home. Meanwhile, Nemiro's (2020) rubric is ideal for evaluating direct behaviors and is best suited for short-term, specific group collaboration activities in the classroom.

This study employs a complementary combination of the Co-Measure and Nemiro tools to assess students' collaborative behaviors in STEM activities. The evaluation uses a scoring scale ranging from 4 (Exemplary) to 0 (Not Performed), with scores assigned based on the frequency and quality of student participation in the various collaborative tasks. This approach ensures alignment with the specific indicators of collaborative competence outlined in the 2018 Vietnam General Education Curriculum, as illustrated in Figure 2.

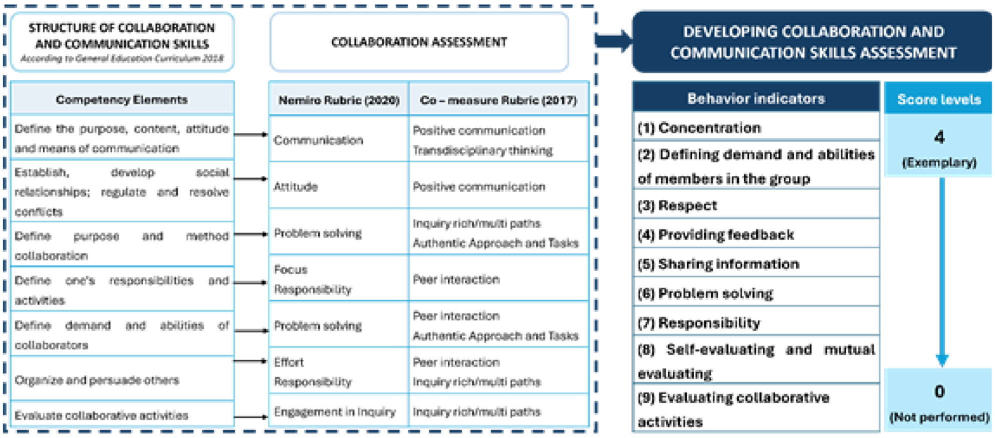

Figure 2. Comparison Table for Students' Collaborative Behaviors

RESULTS AND DISCUSSION

In offline learning phase, Activity 1 and part of Activity 2 were conducted in the classroom, where students received direct guidance from the teacher. As a result, there was a high level of information sharing and collaboration among all participants. In Activity 1, implementing the Numbered Heads Together activity enabled most students to clearly define their roles, establish criteria for the LED card project, and assume responsibility for their assigned tasks. Using this strategy effectively encouraged active participation and ensured that each student contributed to the group's efforts. Additionally, the Written Brainstorming task enabled students to reflect individually and articulate their ideas before engaging in group discussions, thereby enhancing the overall exchange of background knowledge.

The behavior indicator (3)—respect among students—was expected to develop through Activities 1 and 2, with embedded teaching techniques reinforcing this aspect. We focused on this indicator because it was consistently observable throughout both offline activities. As shown in Figure 3, many students maintained or improved their scores, indicating that offline techniques effectively fostered respectful interactions. However, a few students showed minimal or no growth, suggesting that additional teacher support is needed to ensure all learners consistently demonstrate respectful behaviors.

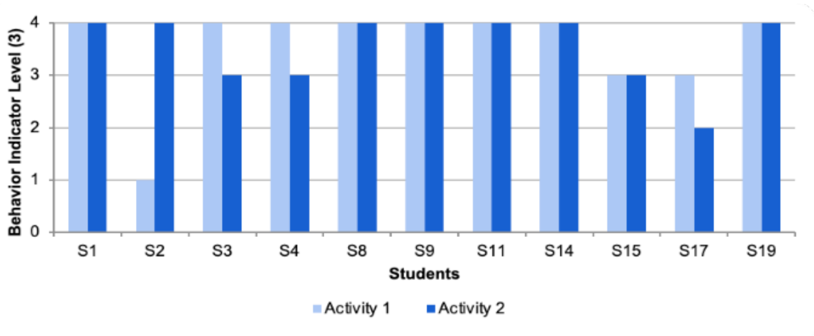

Figure 3. Student's Behavior Indicator (3) - Respect in Activity 1 and 2

The results from the offline phase indicate that most students were actively engaged in collaborative group work, especially when guided by structured tasks such as Numbered Heads Together and Written Brainstorming. These activities supported students in defining roles, contributing ideas, and sharing responsibilities. Notably, behavior indicator (3)—Respect among students—visibly improved in many groups, suggesting that mutual respect was both cultivated and sustained during the learning process. However, the limited progress observed in a few students highlights the need for more targeted teacher support to ensure inclusivity in collaborative competence development.

These findings reinforce the importance of combining relationship-building with a structured instructional approach. Teaching techniques such as Numbered Heads Together and Written Brainstorming not only promote equal participation but also create opportunities for students to recognize and value one another's contributions, which is essential for sustained collaboration. According to research by Johnson et al. (2024), the Numbered Heads Together technique enhances the participation of all group members by asking everyone to prepare answers and contribute. This approach promotes collaboration, minimizes disengagement, and ensures that all members take responsibility and actively contribute to the group's shared objectives.

In the online phase, the most significant challenge of the experimental process was the organization of online learning. Many students did not turn on their cameras or microphones, instead relying solely on text messages in the chat, which reduced both the level of interaction and the degree of collaboration among groups. Nonetheless, the groups maintained sufficient communication to meet the teacher's expectations. All groups successfully described the materials used in their product designs (e.g., type of power supply, switch, LED light) and implemented their ideas for decorating the LED cards.

In Activity 3, students implemented individual design ideas and created visuals using the Padlet.com website. They were then assigned to breakout rooms, where each member presented and defended their design ideas while discussing strengths, weaknesses, and potential challenges. Afterward, each group collaboratively synthesized their group members' individual ideas to create a comprehensive design. Finally, groups reviewed the designs of other groups, exchanging feedback and refining their own designs accordingly. Although this part of the lesson was conducted in an online format, the activity incorporated aspects of the Placemat and Gallery Walk activities through flexible adaptation. The Placemat technique was adapted using Padlet as a shared digital space for collecting and organizing individual ideas before group synthesis. The Gallery Walk was implemented by having students rotate through breakout rooms to present and comment on each group's design. These adaptations maintained the core elements of the original strategies while ensuring their suitability for remote learning. As a result, the activity supported the development of three behavioral indicators: (4) Providing Feedback, (5) Sharing Information, and (6) Problem-Solving.

Overall, the students demonstrated development in their collaborative abilities through the implemented activities. Despite the forced transition from offline to online learning, students continued to engage in collaborative discussions, demonstrating that cooperation remained a key component of the learning process. For instance, in the research knowledge activity, students shared and discussed their ideas, which can be seen in the following observed examples: *"I think the plus-minus sign is the symbol of a battery." "Wire is one of the electrical conductors." "Batteries are power sources."* Moreover, students shared information and feedback about ideas for imaginary experiments: *"Should we put a paperclip in the middle of the electrical circuit?" "You should connect a battery, a switch, a lightbulb, and a cup. The lightbulb is illuminated if the cup is an electrical conductor."* When discussing the materials and design of their products, students made proposals they believed essential to their creations, offering various ideas: *"We should make a foldable card with a square birthday cake in the middle." "Great, so the switches should be a wire-type. When the card is closed, the wire will be cut off, and when the card is opened, the wires will be connected." "To make the card, I think we need two sheets of paper, three wires, a battery tray, one battery, and a switch. Decorate it with flowers, branches, and ice cream cakes with full color."* Meanwhile, the teacher utilized flexible teaching techniques to engage students in providing feedback and sharing information. This approach ensured active participation and supported the problem-solving process by encouraging students to consider multiple perspectives.

According to students' reports, despite the challenges posed by the remote learning environment, they continued to exchange ideas and collaborate to complete the final product, as shown in Figure 4. Students worked on their products at home and outside school hours, actively delegating tasks among group members. The teachers assessed the students' collaboration through the group's logs. In Activity 5, all of the groups except Group 1, whose members were affected by COVID-19, reported on their projects. The groups presented their understanding of product manufacturing, including the materials used for the final product, the process of electrical circuit assembly, and card decoration. Group 2 also highlighted specific challenges encountered during the process.

Figure 4. Official Products of Groups

The rapid transition to remote learning created many challenges, particularly in initiating and sustaining student participation. Without structured planning, online group work often results in unfocused discussions, reducing efficiency (Le et al., 2018). Moreover, because both time and space for collaborative activities are inherently limited in virtual environments, teachers must adopt innovative strategies for organizing and coordinating group work (Buchs et al., 2021; Jurkowski et al., 2024). Teacher supervision and intervention are also more restricted during online group discussions, which contributes to a decline in the quality of collaboration and the overall learning experience (Strauß & Rummel, 2020; Webb et al., 2022). Furthermore, unequal participation among group members further exacerbates these difficulties, as some students contribute minimally, creating imbalances within the group that ultimately diminish the effectiveness of collaborative learning (Baker et al., 2021).

Our assessment indicates that students successfully achieved the natural science competence targets in the LED Card – LIGHT IT UP lesson. For test questions assessing conceptual understanding of electricity, power sources, and conductivity properties (Questions 1, 2, 4, and 5), over 80% of students answered correctly. For higher-order, application-level questions, the percentage of correct answers decreased compared to the basic conceptual questions but remained above 60%. This result is consistent with cognitive load theory, as application tasks require higher-order thinking skills and are typically more challenging for students. Examples of students' responses to two open-ended questions provided in Table 1 illustrate how they applied their knowledge in practical contexts. In the exam, we included two open-ended questions: Question 6, which asked students to define a conductor and provide examples, and Question 9, which required students to specify the conditions necessary for electricity to flow through a conductor and illuminate a light bulb. For Question 6, 12 students correctly defined electrical conductivity and provided examples of conductive materials, while 9 students answered only partially. Although 12 students provided correct definitions or examples, none offered a fully complete response that included both. For Question 9, which focused on the conditions for lighting a bulb in an electric circuit, 11 students answered correctly, while 8 students provided relevant content but did not explicitly mention the term "closed circuit." And 2 students did not respond. These findings suggest that collaborative learning may have a limited direct impact on students' acquisition of basic conceptual knowledge. However, at the application stage, teachers should focus on designing learning activities that help students understand the physical principles and apply them in specific contexts. The organization of collaborative learning can greatly promote students' learning outcomes and social development. Previous research also shows that collaborative learning can increase motivation and commitment to education, improving overall learning outcomes (Janssen & Kirschner, 2020). Additionally, when students engage in group activities, they can exchange ideas, learn from one another, and develop critical thinking skills (Gillies, 2023).

Table 1. Students' Answers in Two Open-Ended Questions

Question	Students' answer
Q6. Electrical Conductor Definition and Examples	S1: Electrical conductors are things that can carry electricity through them. Example: zinc, copper, iron,… S11: Electrical conductors are electrical absorbers. Example: metal, gold, steel S3: Electrical conductors are objects that allows electricity to flow through it Example: copper, steel, metal S7: Electrical conductors are the triggers for electricity running in the path. Example: steel, copper, iron,…
Q9. Conditions to create a closed circuit	S2: There must be a power supply to power the light. S4: The condition for electricity to flow through the conductor to light the bulb is that the circuit must be closed. S6: The first condition is the power supply, and the second condition is the closed circuit. S9: It has to be electrical conductors, and the circuit must be closed and the voltage must be applied.

CONCLUSION

Our study demonstrates that integrating structured collaborative teaching techniques into a STEM lesson for 8th-grade students can enhance both their collaborative skills and academic performance. Observations indicate that most groups worked effectively by assigning clear roles, actively sharing ideas, and providing constructive feedback during discussions and design reviews. Additionally, students successfully demonstrated a solid understanding of core electrical concepts and practical proficiency in assembling circuits, reinforcing the value of hands-on, collaborative STEM education.

Beyond achieving immediate learning outcomes, this research contributes to the broader discourse on STEM education by demonstrating how a structured framework fosters collaboration in science classrooms. The findings underscore the potential of incorporating well-established cooperative learning activities, such as Numbered Heads Together, Written Brainstorming, and Gallery Walk, into STEM instruction. These tasks help improve teamwork, student engagement, and long-term knowledge retention. By embedding collaborative practices into STEM education, this approach aligns with Sustainable Development Goal 4 (SDG 4) on quality education and helps cultivate essential interpersonal competencies among learners.

This study was initially intended to include a larger number of participants to enhance the generalizability of the findings. However, due to the disruptions caused by the COVID-19 pandemic, such as student illness and interruptions to regular schooling, only a convenience sample of 21 students was available and able to participate consistently across the sessions. Despite the small number, the study still offers meaningful insights into the value of implementing STEM-based collaborative learning under real-world constraints. Future research should aim to replicate this study with a larger and more diverse student population to provide a stronger basis for generalization.

The shift to online learning also presented several challenges. Many students did not use microphones or cameras and relied mainly on text messaging, which reduced the level of interaction within groups. This limited both the depth and spontaneity of collaboration and made it more difficult for the teacher to observe and support students' group work. These challenges highlight the need for more structured approaches and tools to facilitate collaboration and teacher involvement in online settings.

Finally, although students successfully completed the STEM task and demonstrated some conceptual understanding of electricity and circuits, their performance on application-level questions was less convincing. This suggests that hands-on tasks alone may not be sufficient to promote deeper conceptual understanding. To address this possible shortcoming, future lessons should include more explicit scaffolding, such as teacher-led discussions or structured reflection, to help students connect practical activities with the underlying scientific principles. Further studies could explore how to better align collaborative STEM learning with both procedural and conceptual learning outcomes.

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