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Profile of Collaboration Skills in Learning Renewable Energy Materials

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Abstract: This study aimed to determine students' collaborative skills in renewable energy learning, an essential skill in 21st-century education. This study employed a descriptive approach using qualitative methods to detail the level of students' collaborative skills. Data was collected using a Likert-scale collaborative skills questionnaire. The research subjects consisted of 30 high school students, and data were analyzed using the average percentage scores for each collaborative skill indicator. The results indicated that most students possess relatively high collaborative skills, with the majority scoring above 70%. The average score on the collaboration indicators was 80.33%, with Indicator 1 scoring 81, Indicator 2 scoring 78, and Indicator 3 scoring 82. The respondent with the highest collaboration score was R13, with a score of 97%, while the respondent with the lowest collaboration score was R17, with a score of 25%. The significant variation in scores, ranging from 25% to 97%, indicates substantial differences in student collaboration skills. Factors influencing these skills include ineffective communication, poorly managed differences of opinion, and a lack of empathy toward group members' contributions. The implications of this study underscore the need for collaboration-enhancing strategies, including interpersonal communication training, conflict management, and empathy development within groups. These strategies should be explicitly integrated into project-based learning designs, particularly regarding renewable energy, to enhance students' overall collaboration effectiveness.

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INTRODUCTION

Collaboration is a process of continuous interaction between several people. Collaboration skills can be used to achieve common goals (Konrad et al., 2021; Saks et al., 2025). Fitriyani et al. (2019) explain that academic abilities and collaborative skills should be taught to students, as these can enhance group work among students and determine their success in interacting within society. In general, collaboration is a pattern and form of relationship between individuals or organizations who wish to share, participate fully, and agree or consent to take joint action by sharing information, resources, benefits, and sharing responsibility in making joint decisions to achieve a common goal or to solve various problems faced by those who collaborate (Fitriyani et al., 2019). Therefore, collaboration is important when applied to learning. Cooperation in learning must be instilled as early as possible because collaboration is closely related to students' social and emotional skills (Sari R. et al., 2022).

Collaboration is one of the keys to success in the 21st century. Collaboration is working together, synergizing, adapting to various roles and responsibilities, and respecting differences. When collaborating, individuals cover each other's weaknesses to resolve work/project problems properly. A person is considered to have collaboration skills if they meet the three components of collaboration skills (three dimensions of collaboration), namely: (1) demonstrating the ability to work effectively and value the diversity of team members; (2) showing flexibility and willingness to accept others' opinions in achieving common goals; and (3) sharing responsibility in collaborative work and valuing the contributions of each team member (Trilling, 2009). Meanwhile, the P21 Framework presented by the Buck Institute for Education in Larmer (2015) adds that collaboration is characterized by understanding individual roles

within a group, a mindset of mutual respect, and a spirit of working as a unified whole. Therefore, collaborative skills are crucial to develop in education, particularly in renewable energy education.

However, research on learning practices has found that collaboration skills are not being optimally developed in school environments. Many teachers still apply traditional learning approaches, such as presenting material to students using lecture and question-and-answer methods that are one-way, thus providing little space for students to work together and collaborate in learning activities. As a result, students' collaboration skills are not monitored and appropriately honed. In addition, there is a gap in collaboration skills among students. Saenab et al. (2017) explain that collaboration can occur when group members can work individually. Collaboration also involves the contribution of each individual to recognize and assess productivity and team development. In addition, there are gaps in collaboration skills among students, such as low empathy, poor conflict management skills, and ineffective group communication. These issues are the fundamental reasons for the importance of mapping students' collaboration profiles through structured research.

This gap becomes even more relevant when learning about renewable energy. Renewable energy material requires students to learn about how alternative energy is used and how to determine the need for solar panels on a household scale. Therefore, the material should not be limited to theoretical content (Nurmayasari et al., 2022; Suprapto et al., 2024). This topic is well-suited for development through project-based learning (PBL), which relies on teamwork. Unfortunately, students often face challenges working together to complete complex project-based tasks without adequate collaboration skills.

Therefore, it is important to map students' collaboration profiles in renewable energy learning to determine the extent to which these skills have developed and what needs improvement. This study focuses on 1.) Mapping students' collaboration skills in renewable energy materials, and 2.) Analyzing students' collaboration skills based on three leading indicators through a collaboration questionnaire on renewable energy materials.

METHOD

This study used a descriptive qualitative approach to obtain an in-depth picture of students' collaborative abilities in learning about renewable energy in detail (Devetak et al., 2010). This approach is used to present and explain a comprehensive data collection and analysis process, particularly regarding student interactions within groups during the learning process. The research data was collected during the first week of December 2024 at a high school in Central Sulawesi. The research subjects were 11th-grade students involved in learning about renewable energy. The data collected consisted of questionnaire results related to students' collaborative abilities.

Data collection techniques used collaborative questionnaire instruments. Student collaboration ability questionnaires were used to assess students' collaboration abilities in group tasks during the learning process. The questionnaires were used to observe students' collaboration abilities in renewable energy learning, which was compiled based on collaboration indicators used in the study, comprising three indicators with nine descriptors (presented in Table 1). The learning model used is Project-Based Learning, which was chosen because it allows students to collaborate in groups, solve real-world problems, and produce final products related to renewable energy content. During the learning process, students were divided into several groups and given a project task to design the requirements for a household-scale solar panel based on energy data simulations. Learning activities within each group involved discussions, task distribution, joint decision-making, and presentation of group work results. These activities directly encouraged student interaction and provided opportunities to observe how students demonstrated their collaborative skills in the learning context.

Table 1. Description of Student Collaboration Abilities (Barus, 2020)

No.	Indicators	Descriptors	Code
1.	Know your own responsibilities in the group	I prepare myself well to work in groups before the project starts	A
		I understand information related to the topics and projects being worked on by the group	B

No.	Indicators	Descriptors	Code
		I can provide evidence and ideas to help the group complete agreed tasks	C
2.	Show mutual respect for fellow group members	I am always polite and kind to all group members while working together	D
		I respect and acknowledge the opinions of other members even if they differ from mine	E
		I express disagreement in a diplomatic way to group members	F
3.	Work as a united group	I utilize the strengths of each group member to solve problems related to our assignment	G
		I am actively involved in developing ideas or creating products according to group project objectives	H
		I am open to receiving criticism from group members to improve the results of my work	I

The assessment technique in the questionnaire was carried out by checking the descriptor columns A to J to see if the behavior corresponding to the descriptor was observed. The research data from the questionnaire results were then converted into percentages using the following equation (Nurmayasari et al., 2022).

a. Formula for student collaboration abilities

$$\text{Value} = \frac{\text{Number of visible Descriptor Scores}}{\text{Total number of descriptors}} \times 100 \qquad (1)$$

b. The formula for the average percentage of students' collaboration ability scores

$$\text{Value} = \frac{\text{Total Score of All Students}}{\text{Number of All Students}} \times 100 \qquad (2)$$

The student argumentation ability questionnaire data was then summarized using the Reference Point Assessment (PAP). PAP is an assessment technique that compares the scores obtained by students with an absolute standard or norm (Alfath, 2019). The PAP described by Widyoko (in Nurmayasari et al., 2022) used to categorize students' skills is as follows.

Table 2. Criteria for Student Collaboration Skills

Value	Category
>80	Highly Collaborative
>60 - 80	Collaborative
>40 - 60	Quite Collaborative
>20 - 40	Less Collaborative
≤20	Not Collaborative

Source: Widyoko in (Rahmawati et al., 2019)

Students' collaboration skills were assessed using a questionnaire that evaluated their collaboration abilities in learning activities. In learning collaboration skills, the researchers set the average score for students' collaboration abilities at 70%.

RESULT AND DISCUSSION

The study's results found that students' collaborative skills improved after participating in project-based learning on renewable energy. This was demonstrated by the results of a questionnaire completed by 30 respondents, which showed that most students were in the collaborative to highly collaborative category.

Learning was conducted using the Project-Based Learning (PjBL) approach, which explicitly encourages teamwork, role sharing, and collaborative problem-solving. In this process, students were divided into heterogeneous groups and asked to design and present projects related to renewable energy. As observed in the survey results, this learning process directly contributes to forming a collaborative profile. Data on the level of success in collaborative skills related to renewable energy material is analyzed using descriptive analysis, presented in Table 3.

Table 3. Data on Student Collaboration Ability

No	Student Name	Value	Criteria
1	R1	75	Collaborative
2	R2	83	Very Collaborative
3	R3	75	Collaborative
4	R4	75	Collaborative
5	R5	58	Quite collaborative
6	R6	83	Very Collaborative
7	R7	81	Very Collaborative
8	R8	75	Collaborative
9	R9	75	Collaborative
10	R10	81	Very Collaborative
11	R11	78	Collaborative
12	R12	83	Very Collaborative
13	R13	97	Very Collaborative
14	R14	86	Very Collaborative
15	R15	75	Collaborative
16	R16	25	Quite collaborative
17	R17	94	Very Collaborative
18	R18	75	Collaborative
19	R19	67	Collaborative
20	R20	81	Very Collaborative
21	R21	75	Collaborative
22	R22	75	Collaborative
23	R23	75	Collaborative
24	R24	89	Very Collaborative
25	R25	72	Collaborative
26	R26	78	Collaborative
27	R27	94	Very Collaborative
28	R28	75	Collaborative
29	R29	92	Very Collaborative
30	R30	67	Collaborative
Average		77	Collaborative

The calculations that have been carried out show that the total score of all 2314 students divided by the total number of students is 77% in the collaborative category. This percentage is in line with the target of 70% for learning. Thus, the designed learning has generally improved students' collaborative skills in renewable energy material. However, it was found that two respondents (R5 and R16) still fell into the moderately collaborative category. This was because R16 tended to be passive and did not actively participate in group discussions. When other members were discussing, this student only listened or shifted their attention to different activities.

Meanwhile, R5 appeared hesitant in expressing opinions, so when allowed to speak, the student tended to defer decisions to others without voicing their opinions. This suggests a lack of role-taking and difficulty in articulating ideas openly. This situation suggests that while project-based learning has been effective for most students, there is a need to provide individual support for students with low collaborative skills, particularly in terms of personalized communication training, assigning simple yet

meaningful roles, giving guidance during discussions, and focusing assessments on the process rather than just the project outcomes. The following diagram shows the percentage of collaborative skills for each student in learning about renewable energy.

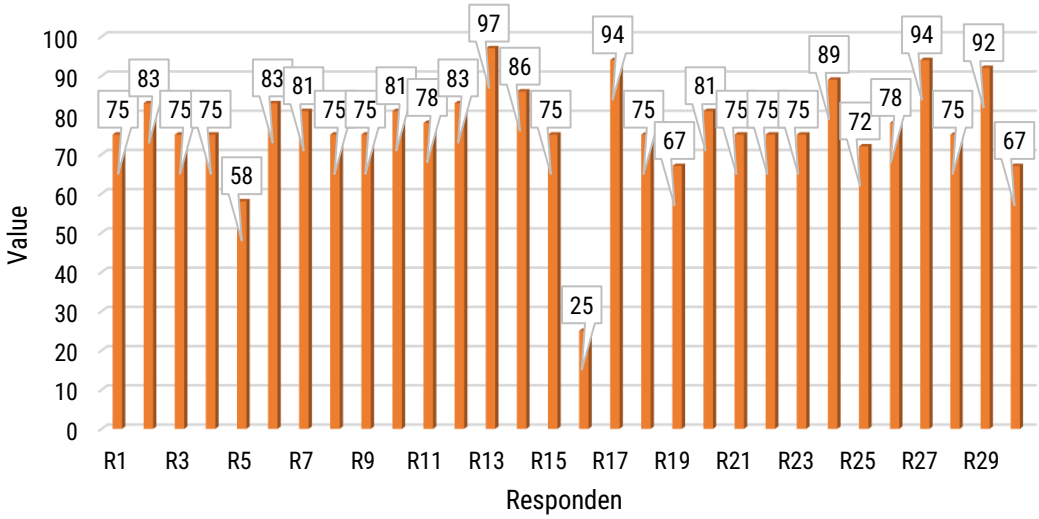

Figure 1. Results of Collaboration Ability for Each Respondent

Most respondents had a relatively high level of collaboration skills, with the majority scoring above 70%. This showed that most students can collaborate well in renewable energy learning. The respondents with the highest collaboration scores were R13, with a score of 97%, followed by R17 and R27, both with a score of 94%. This showed that these respondents have excellent skills in working with others. The respondents with the lowest collaboration score were R17, with a score of only 25%, far below the average. This may indicate specific challenges that need improvement, such as insufficient participation or interpersonal skills. Le et al. (2018) found that students face obstacles in collaboration due to inadequate time to build group relationships, selfish personal tendencies, and a lack of structured roles, which can lead to misunderstandings and hinder effective teamwork and peer evaluation during group projects. Additionally, factors such as those described in the study Simioni et al. (2017) indicate that low participation can hinder student collaboration, as active engagement is crucial for effective teamwork and knowledge sharing. Recognizing and encouraging student contributions fosters a more collaborative environment, enhancing the learning experience.

Furthermore, respondents such as R5 (58%), R29, and R19 (67%) also had below-average scores, indicating a need to pay more attention to students with low collaboration skills. The variation in scores, from 25% to 97%, indicates a significant difference in collaboration skills among students. These striking differences indicate that the collaborative learning process is not yet entirely equitable for all students. This implies the need for more differentiated interventions and personalized learning strategies, particularly for students with passive tendencies or communication difficulties. These score differences may also be attributed to individual characteristics, prior experiences, or learning approaches. Sheikhrezaei (2019) revealed that individual factors, such as learning style, dependency, and working memory capacity, significantly impact collaborative problem-solving ability. Specifically, interactions among these characteristics influence accuracy and performance time in group settings, affecting overall collaboration effectiveness. Graesser et al. (2018) explain that differences in factors, such as trust among team members, are crucial for collaboration. If team members do not trust one another, they may be reluctant to share ideas or take risks in discussions, which can reduce the quality of collaboration. Additionally, when team members have different goals or motivations, this can lead to misalignment in collaborative efforts. Collaboration can become ineffective without agreement on shared goals (Thornhill-Miller et al., 2023).

Based on the questionnaire results, the highest indicator value was indicator three, which is working as a group. The following diagram illustrates each indicator in learning about renewable energy.

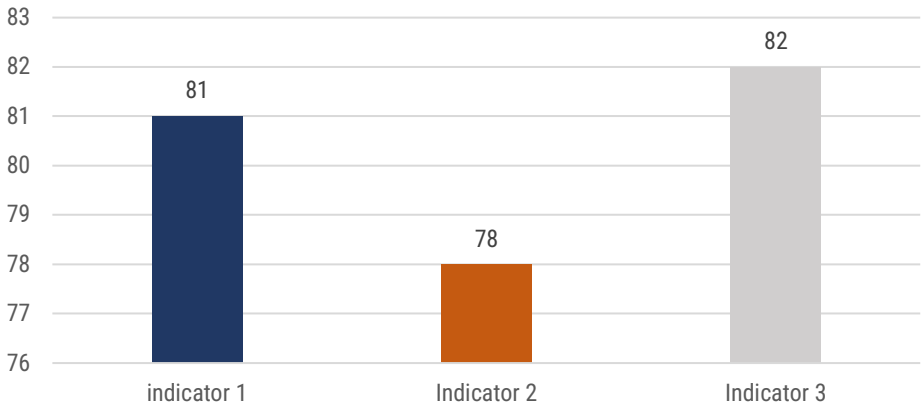

Figure 2. Value Results for Each Indicator of Student Collaboration Skills

Based on the data in the diagram above, it can be seen that Indicator 1, with a score of 81, showed a high score, reflecting that the ability to collaborate in certain aspects of this indicator is already quite good. Several factors can support this indicator, such as effective communication skills, coordination, or a valuable contribution to the team. This indicator showed that most individuals in the group can understand and carry out their respective responsibilities. This indicates that individuals are aware of their roles within the team, including contributing according to the tasks assigned. This good score reflects that the group has a clear task distribution system and a good understanding of individual roles in achieving common goals. Zambrano R. et al. (2023) found that task-specific collaborative experiences enhance student collaboration, as experienced groups showed improved performance and efficiency in learning tasks compared to inexperienced groups, indicating that task sharing can enhance collaborative learning outcomes. In line with this, Asari (2017) explained that task sharing enhances student collaboration by fostering dialogic situations and mutual listening. This enables students to help one another, leading to deeper understanding and retention of material, benefiting struggling and advanced learners in the collaborative learning process.

Next, indicator two received a score of 78, which was lower than the other indicators. This may indicate room for improvement, for example, in certain aspects such as joint decision-making, openness to team members' opinions, or responses to group conflicts. The score on this indicator is slightly lower than that of the other indicators, indicating challenges in fostering mutual respect among group members. The low score may indicate several things, such as a lack of effective communication, poorly managed differences of opinion, or a lack of empathy for the contributions of other members. A lack of effective communication hinders student collaboration by causing misunderstandings, reducing cooperation, and fostering miscommunication. A lack of communication skills hinders student collaboration, as effective collaboration necessitates peer interaction, discussion, and support (Anggraeni Noviasari & Widianingrum, 2023; Fuentes, 2013). Students struggle to engage meaningfully without strong communication skills, reducing collaborative experiences and outcomes in the learning environment (Johler, 2022). Another factor influencing low student collaboration is the poorly managed resolution of disagreements. This is supported by Curseu et al. (2017), who found that disagreements influence collaborative learning, particularly in a socially accepting climate. This acceptance enables most members to thoroughly explore differing viewpoints, thereby enhancing overall group performance and fostering effective student collaboration. Therefore, expressive disagreements among students highlight predictors and their correlations. This suggests that understanding disagreements can enhance student collaboration by addressing communication dynamics, ultimately improving learning experiences and outcomes across various educational contexts (Goke & Violanti, 2024). The final factor influencing the low indicator is a lack of empathy toward others' contributions. Hashim et al. (2019) found that a lack of empathy negatively impacts student collaboration, as empathy fosters cooperation, effective communication, and social coordination, which are essential for successful teamwork in project-based learning environments. This is supported by research showing that a lack of empathy can hinder student collaboration by fostering aggression, tension, and distrust, which disrupts emotional harmony. Building empathetic relationships is

crucial for creating a collaborative climate that encourages understanding and cooperation among all class members (Medina et al., 2018).

Then, for indicator three, the highest score obtained was 82. This score is the highest among the three indicators, indicating that the aspects evaluated in this indicator are of excellent quality. This may include maintaining harmonious working relationships and work efficiency within the team. This reflects the existence of synergy within the group, where each member can unite their contributions for a common goal. This ability can be achieved through good coordination, close cooperation, and commitment to group goals. This is in line with research conducted by Li (2019), which stated that collaborative learning positively influences students' attitudes and confidence in harmonization, fostering harmonious cooperative relationships among participants. Students reported positive engagement and enjoyable collaborative activities, indicating improved interpersonal skills and support in their learning environment. Furthermore, good coordination in student collaboration enhances collaborative knowledge construction, as evidenced by high-performing groups using effective organizational strategies. These groups demonstrate an advanced phase of collaborative writing, indicating that strong coordination positively influences the quality of collaborative outcomes (Mayordomo & Javier, 2015). Factors influencing improved collaboration include a commitment to group goals through student collaboration. This focuses on the compatibility of personal and group achievement goals and their impact on student engagement and performance in collaborative learning environments (Giel et al., 2020). This is supported by research (Anuruthwong, 2017; Hernandez, 2018) on the relationship between commitment to group goals and student collaboration. This focuses on emotional intelligence among leaders and its impact on collaboration among third-grade students during group activities.

With encouragement from indicators of students' collaborative abilities, their collaboration has improved, and they have become more active and productive. As a result, those who previously often relied on each other have become more concerned about the difficulties of their fellow members and more responsible in their discussions. This aligns with research findings (Oikarinen et al., 2022; Widyaningsih, 2017) that group success is highly valued, prompting students to take responsibility for assisting peers who are weaker in terms of ability and skill. Collaborative ability involves shared goals, effective communication, and mutual trust among stakeholders, which enhances collective problem-solving and resource sharing, ultimately leading to improved sustainable outcomes through innovative practices and strengthened partnerships (Meena, 2023).

Research Limitations, advantages, and recommendations

This study has the advantage of focusing on the contextual learning of renewable energy relevant to 21st-century competencies, using standardized collaboration indicators from the Buck Institute and the P21 Framework, and applying Project-Based Learning that encourages student collaboration. However, this study is limited by the use of questionnaires without supporting qualitative data, a small number of respondents from a single school, and a short intervention duration. These findings provide an initial step toward understanding students' collaborative abilities and can help teachers design more effective learning experiences. Further research is recommended to employ mixed methods and compare the effectiveness of various learning models. Additional variables, such as self-efficacy, motivation, and cognitive skills, could also be examined to enhance the understanding of the dynamics of student collaboration.

CONCLUSION

The research results showed that most students have relatively high collaboration skills in project-based renewable energy learning, with an average collaboration score of 77% and most respondents scored above 70%. The respondents with the highest collaboration scores were R13, with a score of 97%, followed by R17 and R27, each with a score of 94%. However, there were also respondents with very low collaboration scores, such as R16, who only scored 25%, and R5 (58%), R30, and R19 (67%), indicating significant variation in collaboration skills among individuals.

The wide variation in scores, ranging from 25% to 97%, indicates a gap in collaboration skills among students. Further analysis shows that factors influencing collaboration include ineffective communication, poorly managed differences of opinion, and low empathy toward the contributions of other members.

Regarding indicators, the collaboration indicator with the highest score is Indicator 3 (82), while Indicator 2 has the lowest score (78). Implications: Collaborative learning requires support from communication training and role-facilitation strategies. Further research is recommended using mixed methods, expanding the scope of subjects, and exploring variables such as self-efficacy and motivation to gain a deeper understanding of the factors influencing collaboration.

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