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Analyzing Students' Collaborative Skills Through Self-Assessment in Renewable Energy Project

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Abstract

This study investigated high school students' collaborative skills through self-assessment in a renewable energy project-based learning (PBL) endeavor. A descriptive quantitative approach was applied, involving 75 students engaged in a project on renewable energy. Data were collected using the Collaboration Self-Assessment Tool (CSAT), which consists of 11 Likert-scale items covering interpersonal and intrapersonal domains, along with three open-ended reflection questions. The data were analyzed using the Rasch model with Winstep version 5.10.1.0 to examine the instrument's quality and students' responses. The findings show that the CSAT meets key measurement criteria, including acceptable unidimensionality (39.3% variance explained) and good reliability (person reliability = 0.76, item reliability = 0.90, Cronbach's alpha = 0.81). Most items functioned well, although the Wright Map indicates that the instrument was relatively easy for the students. In terms of performance, students scored higher in intrapersonal skills (82.9%) than in interpersonal skills (77.5%). Most students were categorized at the established level of collaboration, while smaller proportions were at developing and emerging levels. Responses to open-ended questions further suggest that students were able to reflect on their roles and identify ways to improve their collaboration. Overall, CSAT can be used as a practical tool to assess collaborative skills in PBL settings. The results also point to the need for strengthening interpersonal aspects of collaboration and developing more challenging items for future use.

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INTRODUCTION

In the 21st century, mastering collaborative skills is essential for students to effectively address complex real-world challenges. Collaborative skills are defined as an integration of cognitive and social dimensions that interact during the process of collaborative problem-solving (Chai et al., 2024). These skills enable learners to work productively in teams, communicate ideas clearly, and solve problems collectively. One instructional approach that has been widely recognized for fostering such competencies is Project-Based Learning (PBL). Through engagement in authentic and meaningful projects, PBL encourages active collaboration and supports the development of higher-order thinking skills, particularly in science learning contexts such as renewable energy (Aifah et al., 2024; Hinyard et al., 2018; Maulidah et al., 2023; Rachmawati et al., 2025). Project-based learning has also been widely recognized as an effective approach to develop 21st-century skills, particularly collaboration and problem-solving (Bell, 2010). Furthermore, collaborative skills are considered as a core component of global 21st-century competencies, emphasizing communication, teamwork, and social interaction (Voogt & Roblin, 2012)

Previous studies have demonstrated that collaborative skills encompass several key aspects, including effective teamwork, clear communication, shared responsibility, and adaptability during problem-solving processes (Rahmanniar et al., 2024). However, collaboration is not a simple process, as it involves complex cognitive and social interactions such as negotiation, shared understanding, and collective decision-making (Dillenbourg, 1999). These skills are essential for preparing students to face the challenges of the Fourth Industrial Revolution, which emphasizes teamwork and collaborative problem-solving (Hendrawati et al., 2024). In physics education, collaborative learning has been shown to enhance students' conceptual understanding through active discussion and the exchange of ideas (Simamora et al., 2022). Furthermore, strategies such as assigning specific roles, implementing real-world experiments, and incorporating formative assessments have been identified as effective ways to promote. Among these strategies, self-assessment plays a significant role in encouraging students to reflect on their learning processes, evaluate their contributions, and develop a sense of responsibility within group work (Hinyard et al., 2021).

Despite the growing body of research on PBL and collaborative skills, several limitations remain. Most previous studies have focused primarily on learning outcomes such as critical thinking and problem-solving, while less attention has been given to analyzing the collaborative process itself. In addition, the assessment of collaborative skills is often conducted through external evaluations, such as teacher or peer assessment, which may not fully capture students' internal reflections on their own performance. Furthermore, while renewable energy is recognized as a vital global issue in physics education, it remains an abstract concept that poses significant learning challenges for students (Rachmawati & Wiyatmo, 2025). Addressing renewable energy topics requires an interdisciplinary and comprehensive view across curriculum boundaries, as it heavily relates to real-world phenomena and global challenges (Febriansari et al., 2022). Solving such multifaceted problems cannot be achieved individually; rather, it demands complex collaborative processes where students must work productively in teams to navigate these socio-scientific challenges (Rachmawati & Wiyatmo, 2025). Therefore, evaluating how students perceive their own team interaction during a renewable energy project is crucial. The use of self-assessment as a reflective tool to systematically analyze students' collaborative skills, particularly within the context of renewable energy projects in physics education, remains limited. Therefore, there is a need to explore how self-assessment can provide deeper insights into students' collaborative processes.

This study aims to analyze students' collaborative skills through self-assessment in renewable energy-based project-based learning. Specifically, this research seeks to answer the following question: How are students' collaborative skills characterized based on self-assessment data in renewable energy-based PBL? The findings of this study are expected to contribute to the development of more reflective and student-centered assessment strategies, as well as to support the integration of collaborative and sustainable learning practices in physics education.

METHODS

This study employed a descriptive quantitative design to analyze students' collaborative skills through a self-assessment instrument. The Rasch model is used to objectively evaluate the quality of the instrument, including item suitability, reliability, student ability distribution, and the application of invariant measurement principles (Boone, 2014;

Englehard, 2013; Sumintono & Widhiarso, 2015). Additionally, this model can map the linear relationship between question difficulty and student ability (Bond & Fox, 2015).

The study was conducted from April to May 2025 at a senior high school in Bandung, West Java, Indonesia. The participants consisted of 75 students from two classes selected using purposive sampling from a total of ten classes. The selection was based on the opportunity to implement renewable energy-based project learning.

The instrument used in this study was a collaborative skills self-assessment rubric adapted from the Collaboration Self-Assessment Tool (CSAT) developed by St. Cloud State University. The instrument consisted of 11 items measured using a four-point Likert scale ranging from very low to very high. These items covered two main domains of collaborative skills, namely interpersonal and intrapersonal aspects, including communication, teamwork, responsibility, problem-solving, time management, and self-reflection. The distribution of items across these domains is presented in Table 1.

Table 1 Student collaboration questionnaire

No	Domain	Indicator	Statement Numbers
1	Interpersonal	Idea contribution	1
		Team support	5
		Problem-solving	7
		Team dynamics	8
		Interaction with others	9
2	Intrapersonal	Motivation/participation	2
		Quality of work	3
		Time management	4
		Role flexibility	10
		reflection	11

Content validity was ensured through expert judgment, while construct validity and reliability were evaluated using the Rasch model. Data analysis was conducted using the Rasch model with Winsteps software (version 5.10.1.0). The Rasch analysis was used to examine item fit, person and item reliability, and the distribution of students' ability levels.

Item fit was evaluated using Outfit Mean Square (MNSQ), Z-standardized (ZSTD), and Point Measure Correlation (Pt Measure Corr) indices based on established Rasch measurement criteria. The interpretation of these indices is presented in Table 2, while Table 3 provides the classification of item fit quality.

Table 2 Interpretation of values: Outfit MNSQ, ZSTD, and Pt Measure Corr

Criteria	Acceptable value
Outfit Mean-Square (MNSQ)	0.5 < MNSQ < 1.5
Outfit Z-Standard (ZSTD)	-2.0 < ZSTD < 2.0
Pt Measure Corr	0.4 < Pt Measure Corr < 0.85

(Sumintono & Widhiarso, 2015)

Table 3 Interpretation of question item quality

Criteria of Fit-Statistical Value	Interpretation
The three value criteria are met	Very suitable
Two of the three value criteria are	Suitable
One of the three value criteria met	Less suitable
All value criteria are not met	Not suitable

(Sumintono & Widhiarso, 2015)

Reliability analysis was conducted using person reliability, item reliability, and Cronbach's alpha, with their interpretation criteria presented in Table 4 and Table 5. A Wright map (person-item map) was also used to visualize the alignment between students' ability levels and item difficulty.

Table 4 Interpretation of person reliability and item reliability values

Person Reliability dan Item Reliability Value	Interpretation
> 0.94	Excellent
0.91 – 0.94	Very good
0.81 – 0.90	Good
0.67 – 0.80	Moderate
< 0.67	Weak

Source: Sumintono & Widhiarso (2015)

Table 5 Interpretation of Cronbach's Alpha values

Cronbach Alpha Value	Interpretation
> 0.80	Very good
0.71 – 0.80	Good
0.61 – 0.70	Moderate
0.50 – 0.60	Low
< 0,50	Very low

Source: Sumintono & Widhiarso (2015)

In addition, descriptive analysis was used to describe students' collaborative skills by converting raw scores into percentages for both interpersonal and intrapersonal domains, which were then categorized into levels of collaboration.
The systematic procedure of this research, spanning from the preparation stage, implementation of renewable energy-based project-based learning, to data collection and analysis, is illustrated in Figure 1.

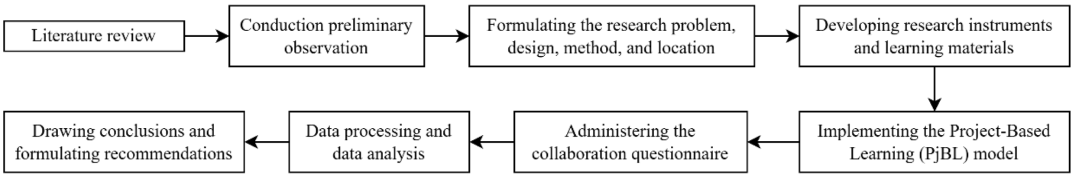

Figure 1 Flowchart of research procedures

Data were collected from students after completing the self-assessment instrument immediately following the completion of the renewable energy-based, project-based learning activities.

RESULTS AND DISCUSSION

Instrument Quality Based on Rasch Analysis

The Rasch analysis indicated that the instrument met the requirement of unidimensionality, with a raw variance explained by measures of 39.3% and an unexplained variance in the first contrast of 10.1%. These results suggest that all items consistently measure a single construct, namely collaborative skills. This finding supports the use of the Rasch model in evaluating instrument quality, as it enables the assessment of construct validity and item functioning in a consistent and systematic manner (Razali et al., 2016). In line with previous studies, acceptable reliability coefficients and item fit statistics indicate that an instrument can measure constructs consistently and accurately (Ying & Tiemann, 2024).

Item fit analysis showed that 10 out of 11 items met the acceptable fit criteria, indicating strong alignment between students' response patterns and model expectations. Rasch measurement guidelines recommend that infit and outfit MNSQ values fall within an acceptable range to ensure item compatibility with the measured construct (Razali et al., 2016). Although one item related to team support showed a slightly low Pt Measure Corr (0.30), it was retained due to its theoretical relevance as an essential component of collaborative skills (Johnson & Christensen, 2020). Similar practices have been reported in previous studies, where items that did not fully meet statistical criteria were retained after refinement based on theoretical considerations and expert judgment (Razali et al., 2016). This finding highlights that item evaluation should consider both statistical indicators and conceptual relevance. The results of the item fit analysis are presented in Table 6.

Table 6 Item Fit Statistics Based on Rasch Analysis

Item Number	Outfit Value		Pt Measure Corr.	Criteria	Interpretation
	MNSQ	ZSTD			
1	1.15	0.93	0.51	All three value criteria are met	Highly suitable
2	0.82	-1.12	0.60	All three value criteria are met	Highly suitable
3	1.01	0.14	0.61	All three value criteria are met	Highly suitable
4	0.80	1.32	0.66	All three value criteria are met	Highly suitable
5	1.41	1.52	0.30	Two of the three value criteria are met	Suitable
6	0.81	-1.14	0.68	All three value criteria are met	Highly suitable
7	1.10	0.66	0.52	All three value criteria are met	Highly suitable
8	0.81	-1.14	0.68	All three value criteria are met	Highly suitable
9	0.77	-1.04	0.53	All three value criteria are met	Highly suitable
10	1.32	1.74	0.51	All three value criteria are met	Highly suitable
11	0.91	-0.54	0.57	All three value criteria are met	Highly suitable

The reliability analysis revealed that the person's reliability was 0.76, indicating a sufficient level of consistency in students' responses. Meanwhile, item reliability reached 0.90, suggesting that the instrument has strong stability in measuring collaborative skills across respondents. In addition, the Cronbach's alpha value of 0.81 indicates good internal consistency among the items. Previous studies have also indicated that Cronbach's alpha values above 0.80 reflect high reliability in instrument measurement (Razali et al., 2016). Overall, these results confirm that the instrument is suitable for assessing collaborative skills in a project-based learning context. The results of the reliability analysis are presented in Figure 2.

```
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      35.6      11.0        1.90    .57                                 |
|  SEM        .6        .0         .16    .03                                 |
| P.SD       4.8        .0        1.36    .28                                 |
| S.SD       4.8        .0        1.37    .28                                 |
| MAX.      44.0      11.0        5.88   1.85                                 |
| MIN.      22.0      11.0       -1.11    .45                                 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .67 TRUE SD    1.19  SEPARATION  1.78  Person RELIABILITY  .76 |
|MODEL RMSE    .64 TRUE SD    1.21  SEPARATION  1.89  Person RELIABILITY  .78 |
| S.E. OF Person MEAN = .16                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .95
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .81  SEM = 2.06
STANDARDIZED (50 ITEM) RELIABILITY = .94

     SUMMARY OF 11 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN     242.5      75.0         .00    .20      1.01   -.02    .99   -.12 |
|  SEM       5.4        .0         .21    .01       .08    .42    .07    .35 |
| P.SD      17.1        .0         .68    .02       .24   1.33    .21   1.11 |
| S.SD      17.9        .0         .71    .02       .26   1.40    .22   1.16 |
| MAX.     273.0      75.0        1.23    .24      1.56   2.64   1.41   1.74 |
| MIN.     208.0      75.0       -1.32    .18       .75  -1.52    .77  -1.32 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .21 TRUE SD     .64  SEPARATION  3.04  Item   RELIABILITY  .90 |
|MODEL RMSE    .20 TRUE SD     .65  SEPARATION  3.24  Item   RELIABILITY  .91 |
| S.E. OF Item MEAN = .21                                                     |
-------------------------------------------------------------------------------
```

Figure 2 Result of person and item reliability and Cronbach's alpha value

Students' Collaborative Skills Profile

The analysis of item difficulty showed that the instrument covered a range of difficulty levels, with logit values ranging from −1.32 to 1.23. Most items were categorized as easy to moderate, consisting of 6 easy items, 4 difficult items, and 1 very difficult item. This suggests that while the instrument captures variation in student ability, it is generally more accessible for most respondents. The distribution of item difficulty categories is shown in Table 7.

Table 7 Distribution of item difficulty levels

Criteria	Frequency	Percentage (%)
Easy	6	54.6
Difficult	4	36.4
Very difficult	1	9.0

The Wright Map further illustrates the relationship between students' abilities and item difficulty. The distribution of person ability and item difficulty is presented in Figure 3.

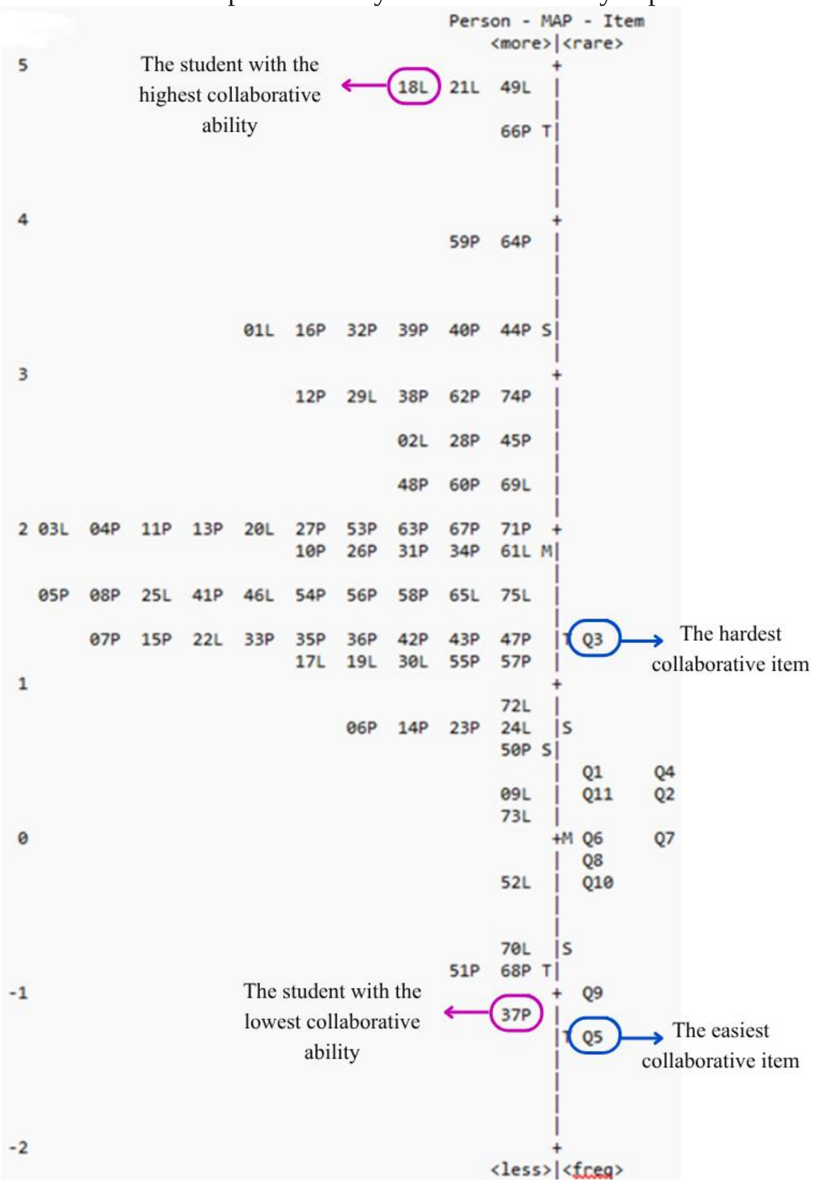

Figure 3 Wright map of person ability and item difficulty in collaborative skills self-assessment

The Wright Map shows that most students are located at higher logit levels (around +2 to +5), while the items are concentrated between 0 and +2 logits. This indicates a mismatch between item difficulty and student ability. This finding aligns with previous research emphasizing that a high-quality assessment instrument should be able to differentiate between various levels of student ability (Ying & Tiemann, 2024). When item difficulty does not adequately cover higher ability levels, the instrument becomes less sensitive in identifying advanced competencies. Therefore, self-assessment should ideally be complemented with other assessment methods, such as peer and teacher evaluations, to obtain a more comprehensive profile of collaborative skills (Pásztor-Kovács et al., 2026). This also suggests the need to develop more challenging items to better capture advanced competencies.

Further analysis of individual items revealed that item Q3 (“I listen carefully to my team’s ideas before making a decision”) had the highest logit value, indicating that it is the most difficult behavior for students to demonstrate. This suggests that active listening and integrative decision-making require higher levels of cognitive and socio-emotional skills. In contrast, item Q5 (“I always show a positive attitude toward the team”) had the lowest logit value, indicating that it is the easiest behavior and commonly demonstrated by students. This pattern reflects a hierarchy of collaborative skills, where basic affective behaviors (e.g., maintaining a positive attitude) are easier to demonstrate, while higher-order skills (e.g., active listening and decision-making) require more complex competencies. Similar findings have been reported by Mahtari et al., (2024), who noted that communication and individual responsibility are among the most challenging aspects of collaboration.

Domain-Based Analysis of Collaborative Skills

The analysis of collaborative skills across domains showed that students achieved an average score of 77.5% in the interpersonal domain and 82.9% in the intrapersonal domain. This indicates that students tend to demonstrate stronger abilities in self-management aspects compared to social interaction within groups. This finding suggests that students demonstrate relatively stronger self-regulation in managing their own roles, responsibilities, and participation during group work. This aligns with prior research showing that collaborative problem solving varies across contexts depending on task demands (Andrews-Todd et al., 2023). It also supports the view that self-regulated learning plays an important role in monitoring and improving learning processes (Panadero, 2017). This pattern is also aligned with previous literature, indicating that although collaborative learning strengthens teamwork and communication skills, students often show limited engagement in interpersonal interaction and require structured support to improve communication effectiveness and participation in group activities (Ula et al., 2025).

However, students still face challenges in interpersonal aspects such as expressing ideas, engaging in discussions, and managing group dynamics. This is aligned with previous findings showing that communication and face-to-face interaction are among the most challenging components of collaboration (Mahtari et al., 2024). Overall, self-regulation tends to develop earlier than interpersonal communication skills in collaborative environments. The distribution of students’ collaborative skill levels is presented in Table 8.

Table 8 Distribution of students’ collaborative skill categories

Collaborative Category	Score Range	Students	Percentage (%)
Emerging Collaboration	10–25	4	5.3%
Developing Collaboration	26–34	21	28.0%
Established Collaboration	35–44	50	66.7%
Total		**75**	**100%**

As shown in Table 8, most students (66.7%) were categorized as “established,” indicating consistent participation and contribution in teamwork. Meanwhile, 28.0% were in the “developing” category, and 5.3% were still in the “emerging” category, suggesting that a small proportion of students require additional support to develop basic collaborative skills. These results highlight the importance of instructional strategies that not only promote individual responsibility but also explicitly train interpersonal communication and group interaction skills. Structured activities such as role rotation, guided discussion, and conflict resolution tasks may help balance the development of both domains.

Qualitative Findings from Open-Ended Responses

The qualitative analysis of students' responses to open-ended questions provides deeper insights into their collaborative experiences. Overall, students demonstrated increased self-awareness regarding their strengths and weaknesses in collaboration. Many students acknowledged difficulties in actively listening, contributing ideas, and participating in discussions, which supports the quantitative findings related to higher item difficulty in communication-related indicators.

Students also identified specific areas for improvement, such as communication skills, emotional regulation, and active participation. In addition, they proposed practical actions such as respecting others' opinions, reducing ego, asking questions, and engaging more actively in group discussions. These findings indicate that students perceive collaboration not only as task completion but also as an interpersonal process that involves mutual respect, empathy, and active engagement. The alignment between qualitative reflections and quantitative results strengthens the validity of the instrument and demonstrates that self-assessment can effectively promote reflective thinking.

Overall, this study demonstrates that the integration of self-assessment and Rasch analysis provides a robust framework for evaluating students' collaborative skills in project-based learning. The empirical validation presented in the psychometric analysis confirms that the instrument possesses high construct validity. As indicated by the unidimensionality data, the raw variance explained by measures reached 39.3%, which safely exceeds the minimum threshold of 20%, proving that all items strictly assess a single underlying trait of collaboration. This quantitative verification is also reflected in the item fit analysis, where 10 out of 11 items fully satisfied the acceptable fit criteria.

The findings confirm that while students generally exhibit good levels of collaboration, there is a clear imbalance between intrapersonal and interpersonal competencies. Specifically, students showed higher performance in intrapersonal skills (82.9%) compared to interpersonal skills (77.5%), suggesting that self-regulation and individual responsibility tend to develop more readily than social interaction. This structural gap is explicitly mapped in the overall student distribution data, showing that while 66.7% of the sample reached the "established" level, a substantial 28.0% are still in the "developing" stage of collaboration.

The results also indicate that higher-order collaborative skills, such as active listening and integrative decision-making, remain challenging for students. This condition reflects the uneven development of collaborative competencies across different skill domains, where more complex interactional skills require greater cognitive and social effort. Supporting this interpretation, Mahtari et al. (2024) emphasize that communication and responsibility are among the most demanding components of collaboration compared to basic collaborative behaviors. In this study, this difficult hierarchical pattern is clearly evidenced by the item difficulty parameters, where item Q3 regarding careful listening to team ideas had the highest logit value, making it the hardest behavior to demonstrate, whereas item Q5 regarding a positive attitude had the lowest logit value.

From a theoretical perspective, collaboration involves complex cognitive and social processes, such as negotiation, perspective-taking, and shared decision-making (Dillenbourg, 1999), which explains the difficulty of developing higher-order skills. This also highlights the need for appropriate assessment approaches to capture such complexity (Cheruiyot & Molnár, 2026; Rojas et al., 2021). This interactional complexity is profoundly amplified within the multidisciplinary context of renewable energy projects. As emphasized by Rachmawati and Wiyatmo (2025), the inherently abstract nature of renewable energy concepts introduces distinct conceptual challenges for high school students. Navigating these socio-scientific topics demands a comprehensive, cross-curricular perspective that integrates physics calculations with technical and environmental factors (Febriansari et al., 2022). Consequently, when students face the heavy cognitive load of a renewable energy project, their limited socio-emotional capacity causes them to prioritize individual task management (intrapersonal) over complex group negotiations (interpersonal). Therefore, collaborative learning should not rely solely on group tasks but must include structured training in communication and interaction skills. As Johnson and Johnson (2009) emphasize, effective collaboration requires intentional structuring rather than assuming it develops naturally. CPS research further supports that no single task can fully capture collaborative competence, indicating the need for multiple structured assessments (Andrews-Todd et al., 2023).

Furthermore, the integration of self-assessment within Project-based learning serves both as an evaluation tool and a reflective learning strategy. Questionnaire-based approaches are commonly used to assess collaborative skills through students' self-reports (Cheruiyot & Molnár, 2026; Rojas et al., 2021). Project-based learning environments should be designed not only to engage students in tasks but also to explicitly develop collaboration as a 21st-century competency (Bell, 2010; Voogt & Roblin, 2012). Through this process, students are encouraged to recognize their roles, identify areas for improvement, and take responsibility for their learning processes.

The qualitative findings reinforce this interpretation, showing that students develop greater self-awareness and are able to propose concrete actions to improve their collaborative behavior. This suggests that self-assessment contributes to students' social metacognition in collaborative learning environments. However, previous studies have shown that students tend to overestimate their collaborative abilities, suggesting the need for cautious interpretation of self-reported data (Pásztor-Kovács et al., 2026).

In addition, the Wright Map analysis shows that most students' ability levels exceed the difficulty of the items, suggesting that the instrument may not be sufficiently sensitive to differentiate higher-level collaborative skills. The empirical visualization in Figure 2 explicitly illustrates this psychometric mismatch, mapping the majority of student abilities at higher positions (+2 to +5 logits) relative to the item difficulties concentrated between 0 and +2 logits. An effective assessment instrument should include a balanced distribution of item difficulty across logit scales to capture both low and high ability levels (Ying & Tiemann, 2024). Therefore, the development of more challenging items—specifically designed to target sophisticated team synthesis and peer negotiation— is recommended to better capture advanced collaborative competencies and optimize item targeting.

In terms of contribution, this study provides empirical evidence on the use of a self-assessment instrument analyzed through the Rasch model in the context of renewable energy-based physics education. It also offers practical implications for educators in designing more balanced and reflective collaborative learning environments.

However, this study has several limitations. The use of self-reported data may introduce bias, as students may overestimate or underestimate their collaborative abilities. This finding is supported by previous research indicating that students tend to overestimate their collaborative abilities and rate themselves above average, which may reduce the objectivity of self-assessment results (Pásztor-Kovács et al., 2026). In addition, the sample was limited to a single school context, which may affect the generalizability of the findings.

Future research is recommended to incorporate multiple assessment sources, such as peer and teacher evaluations, and to involve a broader sample, to obtain a more comprehensive understanding of collaborative skills. A multi-method approach is particularly important, as CPS assessment literature highlights the use of complementary methods such as human-human interaction, human-agent systems, and questionnaire-based instruments (Cheruiyot & Molnár, 2026). This combination strengthens the validity of collaborative skill measurement and reduces reliance on a single perspective (Razali et al., 2016).

CONCLUSION

This study concludes that the collaborative self-assessment instrument demonstrates good quality in measuring students' collaborative skills within renewable energy-based project-based learning. The Rasch analysis confirms that the instrument is both valid and reliable and capable of distinguishing different levels of students' collaborative abilities.

The findings reveal that students tend to exhibit stronger intrapersonal skills compared to interpersonal skills, indicating that self-regulation develops more readily than social interaction in collaborative settings. Although most students fall within the "established" category, higher-order skills such as communication and active engagement in group processes remain areas that require further development. These quantitative results are supported by qualitative findings, which show that students gain increased self-awareness and demonstrate a willingness to improve their collaborative behavior through reflection.

Overall, the study shows that self-assessment in project-based learning functions not only as an assessment tool but also as a mechanism that supports reflective learning and collaborative skill development. The results also suggest the need to refine the instrument by including more challenging items to better capture higher levels of collaborative competence.

Despite these strengths, the study has several limitations. The sample was limited to a single educational context, which may restrict generalizability. In addition, the reliance on self-reported data may introduce bias in students' perceived collaborative abilities. The Wright Map analysis further indicates that the instrument tends to be relatively easy, reducing its sensitivity in differentiating higher-level skills. Future research is recommended to involve more diverse samples, integrate multiple assessment methods such as peer and teacher evaluation, and develop more complex items to better represent advanced collaborative competencies.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

K played a leading role in this study, including designing and implementing the project-based learning activities, adapting the Collaboration Self-Assessment Tool (CSAT), and conducting data analysis. LA supervised the research project, providing academic guidance and critical feedback throughout the study. AS contributed by facilitating the research setting and supporting the implementation of Project-based learning in the classroom. BF assisted in observing the research process and contributed to the linguistic adaptation of the CSAT instrument.

AI DISCLOSURE STATEMENT

The authors used AI-based tools to assist in language refinement and clarity of writing. All interpretations, analyses, and conclusions remain the sole responsibility of the authors.

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