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

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Abstract
This study aimed to examine high school students' collaborative skills through self-assessment in a renewable energy project-based learning. A descriptive quantitative approach involved 75 students participating in a renewable energy project. The Collaboration Self-Assessment Tool (CSAT) was employed, comprising 11 Likert-scale items grouped into interpersonal and intrapersonal domains, along with three open-ended reflection questions. Data were analyzed using the Rasch model through Ministep version 5.10.1.0 to assess unidimensionality, item fit, reliability, item difficulty, and Wright Map distribution. The instrument satisfied unidimensionality criteria, with 39.3% variance explained by measures and 10.1% in the first contrast. Person reliability reached 0.76, item reliability was 0.90, and Cronbach's Alpha indicated strong internal consistency at 0.81. Ten of the eleven items demonstrated good fit, with item difficulty ranging from −1.32 to +1.23 logits. Wright Map analysis showed that students' abilities generally exceeded item difficulty, indicating the instrument was relatively easy for the tested group. Students performed better in intrapersonal skills (82.9%) than in interpersonal skills (77.5%). Based on total scores, 66.7% of students were categorized as having established collaboration skills, 28% were developing, and 5.3% were in the emerging category. Open-ended responses supported these findings, highlighting students' self-awareness, willingness to improve, and concrete collaborative actions. Overall, the CSAT instrument proved to be a valid, reliable, and effective instrument for assessing collaborative skills in project-based learning on renewable energy.

Keywords: Collaboration skills · Self-assesment · Project-based learning · Renewable energy

INTRODUCTION

In the 21st century, mastering robust collaborative skills is essential for young learners to address real-world challenges effectively. Project-Based Learning (PBL) stands out as a powerful pedagogical model that cultivates students' ability to collaborate meaningfully. This approach enables students to participate in real-world projects that require active collaboration among learners (Hinyard et al., 2018; Hendrawati et al., 2024; Maulidah et al., 2023; Aifah et al., 2024; Rachmawati et al., 2025). PBL has been proven to enhance teamwork skills while fostering critical and creative thinking, especially in science projects like renewable energy (Aifah et al., 2024; Rahmanniar et al., 2024; Rachmawati et al., 2025).

Previous research shows that collaboration skills include working effectively in teams, communicating clearly, taking responsibility for one's role, and adapting during problem-

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solving (Rahmanniar et al., 2024). 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 practice, collaboration in physics learning has been shown to improve conceptual understanding through idea exchange and active discussion (Simamora et al., 2022). Furthermore, Ferrero et al. (2021) state that collaborative skills can be developed through strategies like assigning specific roles, conducting relevant real-world experiments, and implementing formative assessments, including self-assessment. Using self-assessment in PBL enables students to reflect on their roles, contributions, and progress during teamwork, enhancing their sense of responsibility and independence (Hinyard et al., 2021). This approach also supports the development of "learning to learn" skills necessary for lifelong learning and contributes to achieving the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 7 (Affordable and Clean Energy) (Ferrero et al., 2021).

This research is urgent because it aims to map the development of students' collaborative skills in renewable energy project-based learning, a critical topic amid the current energy crisis. Although previous studies have shown PBL's effectiveness in enhancing 21st-century skills, few have specifically examined the role of self-assessment as a tool for strengthening self-reflection in developing students' collaborative skills, especially in the physics project context related to renewable energy. The key question is: How can students' collaborative skills be improved and monitored through self-assessment in PBL? While peer assessment might be an option, self-assessment offers a more reflective and meaningful way for students to evaluate and understand their interpersonal skills within teamwork (Hinyard et al., 2018).

Therefore, this study focuses on applying and analyzing self-assessment as a means to evaluate and develop students' collaborative skills during PBL on renewable energy topics. The purpose of this study is to analyze students' collaborative skills through self-assessment in renewable energy-based PBL. It aims to contribute to developing learning strategies that incorporate not only project-based activities but also reflection and personal responsibility in teamwork. Practically, the results can help create a more precise and relevant rubric for collaborative self-assessment. The operational definitions in this study are: collaborative skills refer to students' ability to work effectively in groups, demonstrating communication, shared responsibility, conflict resolution, and resource sharing (Rahmanniar et al., 2024). Self-assessment is defined as a reflective tool that students use to honestly evaluate their contributions, strengths, and areas for improvement in their collaborative processes (Hinyard et al., 2018). Ultimately, this research aims to contribute scientifically to the development of a project-based and reflective collaborative learning model, which is vital for shaping a new generation of 21st-century learners-competent, caring, and prepared to face global challenges.

METHOD

Research Design

This study uses a descriptive quantitative approach to analyze students' collaborative skills through self-assessment instruments. 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 (Sumintono & Widhiarso, 2015; Boone, 2014; Englehard, 2013). Additionally, this model can map the linear relationship between question difficulty and student ability (Bond & Fox, 2015).

The Rasch model has been widely used in assessing self-assessment instruments and 21st-century skills. For instance, Putri et al. (2022) applied it to create a competency-based self-assessment instrument for high school students. Similarly, Sukarelawan et al. (2021) utilized it to evaluate the psychometric properties of a metacognitive awareness instrument.

This study was conducted from April to May 2025 at a high school in Bandung, West Java. The school was selected based on accessibility and involvement in project-based learning. This study was designed to evaluate students' collaborative skills during project-based renewable energy learning by assessing the extent to which self-assessment instruments can accurately describe collaborative skills.

Participants

The participants in this study consisted of 75 students from two different classes at a high school in Bandung. From a total of 10 classes at the school, two classes were selected using purposive sampling, considering the opportunities available to implement project-based learning.

Instruments

The instrument employed was a collaborative skills self-assessment rubric, adapted from the Collaboration Self-Assessment Tool (CSAT), developed by The Academy for Co-Teaching and Collaboration at St. Cloud State University (2012). This instrument measures how students assess their engagement in group work during project-based learning. The instrument includes 11 indicators of collaborative skills, covering aspects such as contribution, participation, work quality, time management, team support, problem-solving, role flexibility, and self-reflection. Each item is rated on a 1-4 Likert scale from "very low" to "very high" based on behavioral descriptions. Sample items of this rubric include:
"I routinely use time effectively to ensure tasks are completed on time."
"I consistently participate in group problem-solving with an open mind and value other members' contributions."

Additionally, the indicators in this instrument are categorized into two domains of collaborative skills. The interpersonal domain consists of five indicators reflecting the ability to share ideas and information, collaborative problem-solving, team support, awareness of group dynamics, and social interaction with team members. Meanwhile, the intrapersonal domain includes six indicators, including self-reflection, role flexibility, time management, quality of work outcomes in a team, and active participation in group activities. This classification is used to analyze students' tendencies in terms of self-regulation and social interaction during collaboration.

The Collaboration Self-Assessment Tool (CSAT) used in this study has been validated by its original developers (St. Cloud State University, 2012). Therefore, content and construct validity were not re-tested in this study. However, item fit analysis and reliability were still conducted using the Rasch model to test the instrument's suitability for the new context and respondents.

Data analysis techniques

The data were analyzed using descriptive statistics supported by Ministeps software 5.10.1.0, which employs the Rasch model. This analysis aimed to analyze unidimensionality, item validity and reliability, item fit to the model, respondent ability distribution, logit mapping between participants and items (Wright Map), and prominent and weak skill indicators. The first stage began with a unidimensionality test using Principal Component Analysis (PCA) of Residuals to ensure that all items in the instrument measured one collaborative skill construct. The instrument was deemed unidimensional if the raw variance explained by measures exceeded 20%, and the unexplained variance in the first contrast was less than 15% (Sumintono & Widhiarso, 2015). The following table provides an interpretation of the unidimensionality values of the instrument.

Table 1. Interpretation of the unidimensionality value for the instrument

Raw Variance Explained by Measures Values (%)	Criteria
> 60	Extraordinary
> 40	Compliant
> 20	Fulfilled

The next step is to analyze item validity by evaluating the fit of each item to the Rasch model. This information is obtained from the Item Fit Order table, which lists three main parameters: Outfit Mean Square (MNSQ), Z-Standard (ZSTD), and Point Measure Correlation (Pt Measure Corr.). According to Sumintono & Widhiarso (2015), the criteria for determining whether the obtained values fall within the acceptable range are shown in Table 2.

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

After analyzing the validity of the items, a reliability test was conducted to assess the extent to which the instrument produced consistent and stable results. Three indicators were used in this test, namely person reliability, item reliability, and Cronbach's Alpha. Person reliability indicates the consistency of students' answers, while item reliability measures how stable the items are in measuring the construct. In addition, Cronbach's Alpha represents the overall interaction between students and items. The interpretation of these reliability and Cronbach's Alpha values is presented in Tables 3 and 4 below:

Table 3. Interpretation of Person Reliability and Item Reliability Value

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

Table 4. Interpretation of Cronbach's Alpha Value

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

Next, item difficulty analysis was conducted to evaluate the distribution of items based on respondents' collaborative skills. In the context of Rasch Model-based self-assessment instruments, difficulty levels reflect the tendency of certain items to be answered more frequently by students with higher collaborative skills (Boone, 2014). This analysis helps map the distribution of students' abilities while identifying indicators of collaborative skills that have been mastered dominantly and those that still need to be improved (Sumintono & Widhiarso, 2015).

Table 5. Interpretation of Item Difficulty Levels

Raw Variance Explained by Measures Value (%)	Criteria
Measure Logit > SD	Very difficult
0.00 < Measure Logit ≤ SD	Difficult
-SD < Measure Logit ≤ 0.00	Easy
Measure Logit < -SD	Very Easy

Finally, a visualization of the distribution of student abilities and item characteristics was performed using the Wright Map (Person-Item Map) to identify the extent to which the distribution of student abilities corresponds to the difficulty level of each item. The Wright Map enables comparative analysis between individual abilities and item difficulty on the same logit scale, thereby facilitating researchers in assessing the balance of the instrument and potential disparities between respondent levels and item challenges (Bond & Fox, 2015). This mapping also played an important role in identifying gaps between student competencies and item expectations, as well as detecting whether there were items that were too easy or too difficult for certain respondent groups (Boone, 2014).

In addition to Rasch analysis, manual descriptive analysis using Microsoft Excel was also conducted to obtain an overview of collaborative skills based on two main domains. Scores from each domain (interpersonal and intrapersonal) were summed for each respondent, then converted into percentages using the formula:

$$Domain\ score\ percentage = \frac{Actual\ score}{Maximum\ domain\ score} \times 100\%$$

The maximum score for the interpersonal domain is 20, while for the intrapersonal domain it is 24. These conversion results were used to interpret students' strengths and weaknesses in each domain. Next, the total collaborative score is classified into three categories (emerging, developing, and established) according to the CSAT interpretation guidelines. The percentage distribution of students in each category is presented in tabular form and used to describe the general profile of students' collaborative skills during project-based learning.

RESULTS AND DISCUSSION

The results of this study also fill a gap in research that specifically combines Project-Based Learning on the topic of renewable energy with self-assessment-based collaboration skills evaluation and Rasch analysis. Previous studies have highlighted the enhancement of 21st-century skills through Project-Based Learning, but few have emphasized the use of internationally standardized instruments such as CSAT in the context of renewable energy physics education in Indonesia. Therefore, this study contributes to two areas simultaneously: validating the instrument's validity in a local context and quantitatively and qualitatively mapping students' collaboration skill domains.

The results of this study were obtained from 75 high school students who participated in project-based learning on the topic of renewable energy. The data used were the results of self-assessments of collaborative skills using the Collaborative Skills Assessment Tool (CSAT), which consisted of 11 items on a Likert scale of 1 to 4 and three open-ended questions. The research data were analyzed using descriptive statistics with the help of Ministeps software version 5.10.1.0, which applies the Rasch Model. This analysis aimed to evaluate the quality of the self-assessment instrument for collaborative skills, including unidimensionality, reliability, item validity, item difficulty level, participant ability distribution, and mapping the relationship between items and respondents.

Unidimensionality

The unidimensionality test results showed that the raw variance explained by measures was 39.3% and the unexplained variance in the first contrast was 10.1%. Based on the criteria of Sumintono and Widhiarso (2015), these values indicate that the instrument meets the unidimensionality requirement, meaning that all items consistently measure one construct, namely collaborative skills.

Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Person information units

		Eigenvalue	Observed		Expected
Total raw variance in observations	=	118.6744	100.0%		100.0%
Raw variance explained by measures	=	46.6744	39.3%		39.1%
Raw variance explained by persons	=	33.3876	28.1%		28.0%
Raw Variance explained by items	=	13.2868	11.2%		11.1%
Raw unexplained variance (total)	=	72.0000	60.7%	100.0%	60.9%
Unexplned variance in 1st contrast	=	11.9332	10.1%	16.6%	
Unexplned variance in 2nd contrast	=	10.1532	8.6%	14.1%	
Unexplned variance in 3rd contrast	=	9.0132	7.6%	12.5%	
Unexplned variance in 4th contrast	=	8.2042	6.9%	11.4%	
Unexplned variance in 5th contrast	=	7.7721	6.5%	10.8%	

Figure 1. Results of Person and Item Reliability and Cronbach's Alpha

Item validity

Item validity was analyzed based on its fit to the Rasch model using three main parameters, namely outfit Mean Square (MNSQ), Z-Standard (ZSTD), and Point Measure Correlation (Pt Measure Corr.). Table 6 shows the analysis of the validity of each item in the collaborative skills self-assessment instrument. Of the 11 items tested, 10 items met the three main criteria in the Rasch model, namely outfit Mean-Square (MNSQ) with a range of values from 0.77 to 1.41, Z-Standard (ZSTD) ranging from -1.32 to 1.52, and Point Measure Correlation (Pt Measure Corr.) between 0.51 and 0.68. These items were deemed highly suitable (fit) for the Rasch model as they demonstrated consistency between participants' response patterns and model predictions, as well as strong correlations with the skills being measured.

Meanwhile, one item related to “support for the team” has a Pt Measure Corr. value of 0.30, which is slightly below the recommended minimum threshold of 0.40. However, its MNSQ and ZSTD values remain within acceptable limits at 1.41 and 1.52, respectively. This indicates that, overall, the item still functions as predicted by the model. Since the “support for the team” indicator is an essential dimension of collaborative skills (Johnson & Cristensen, 2020), the item was retained in further analysis. This decision is based on the principle that item validity evaluation is not only quantitative but also considers theoretical relevance and content meaning (Bond & Fox, 2015; Boone, 2014).

The results of each criterion's values are then interpreted based on the fit-statistic criteria in Table 6 below.

Table 6. Interpretation of the fit-statistic value

Fit-Statistic Criteria	Interpretasi
All three value criteria are met	Highly suitable
Two of the three value criteria are met	Suitable
One of the three value criteria is met	Less suitable
None of the value criteria are met.	Unsuitable

Thus, all items remain in use in assessing students' collaborative skills, while recommending a review of these items in the development of the next instrument. Details of the analysis results are shown in Table 7 below and reinforced visually through the Wright Map in the next section.

Table 7. Interpretation Results of Collaborative Self-Assessment Item Quality

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

Instrument reliability

Figure 2 presents the results of the analysis of item reliability, person reliability, and Cronbach's Alpha for the collaborative skills self-assessment instrument. The value of person reliability obtained was 0.76, which indicates an acceptable level of consistency in student responses, categorized as "sufficient" based on Rasch reliability standards. Meanwhile, the item reliability was 0.90, which indicates a good level of item stability in measuring collaborative competence based on the interpretation criteria. Based on the interpretation criteria proposed by Sumintono and Widhiarso (2015), person reliability in the range of 0.70 – 0.79 is considered acceptable, while item reliability above 0.80 is categorized as strong. This suggests that the instrument can distinguish between students with varying levels of collaborative skill and that each item functions consistently across different respondent groups.

Furthermore, the analysis also yielded a Cronbach's Alpha value of 0.81, which demonstrates a high level of internal consistency among the items. This means that students' responses across items were sufficiently aligned, indicating that the items measure the same underlying construct. According to Johnson and Christensen (2), Cronbach's Alpha values above 0.80 represent good internal reliability, supporting the claim that the instrument is suitable for measuring collaborative skills in a project-based learning context.

Overall, the reliability analysis confirms that the instrument provides stable and trustworthy measurements, both from the perspective of respondent behavior and item functionality, thereby supporting its application in educational assessments.

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-------------------------------------------------------------------------------
|          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                                                      |
-------------------------------------------------------------------------------
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Figure 2. Result of Person and Item Reliability and Cronbach's Alpha Value

Item difficulty level

The analysis of item difficulty levels was based on logit values and standard deviations. Of the 75 respondents, three students gave extreme responses, so they did not have logit values that could be analyzed statistically. Therefore, logit analysis and ability distribution were only performed on the 72 non-extreme respondents.

Table 8. Results of Item Quality Interpretation

Item Number	Measure (ME)	Standard Deviation (SD)	Criteria	Interpretation
1	0.46	0.68	0,00 < ME≤ 0,68	Difficult
2	0.29	0.68	0,00 <ME≤ 0,68	Difficult
3	1.23	0.68	ME>0,68	Very difficult
4	0.46	0.68	0,00 <ME≤ 0,68	Difficult
5	-1.32	0.68	-0,68<ME≤0,00	Easy
6	-0.04	0.68	-0,68<ME≤0,00	Easy
7	-0.01	0.68	-0,68<ME≤0,00	Easy
8	-0.12	0.68	-0,68<ME≤0,00	Easy
9	-1.04	0.68	-0,68<ME≤0,00	Easy
10	-0.24	0.68	-0,68<ME≤0,00	Easy
11	0.32	0.68	0,00 <ME≤ 0,68	Difficult

Table 9. Results of Item Difficulty Analysis

Criteria	Frequency	Percentage (%)
Easy	6	54,6
Difficult	4	36,4
Very difficult	1	9,0

Table 9 shows the results of the analysis of the difficulty level of collaborative skill items. Of the 11 items analyzed, the measure values ranged from -1.32 to 1.23 logit. This indicates that the instrument can cover various levels of student ability, although all items are still within the low to moderate difficulty range. Based on the logit distribution classification, 6 items are classified as easy, 4 items as difficult, and 1 item as very difficult. According to Sumintono & Widhiarso (2015), an even distribution of difficulty levels is important to ensure that the instrument can measure students' abilities representatively across the entire skill spectrum. Items with high logits indicate statements that are more likely to be agreed upon by students with high collaborative skills, while items with low logits are easier to agree upon by students with lower skills. Such item composition is beneficial in identifying groups of students who require further support.

Additionally, the instrument has a standard deviation of 0.68 logits, indicating a significant spread of collaborative skills among students. Sumintono and Widhiarso (2015) state that a standard deviation above 0.5 logits indicates a meaningful variation in ability. Thus, this distribution reinforces the urgency of implementing learning strategies that can reach and facilitate the development of students' collaborative skills at various ability levels.

Mapping of abilities and item difficulty (Wright Map)

Figure 3 displays the Wright Map, which illustrates the distribution of students (persons) and the difficulty level of statement items (items) based on the results of the collaborative skill self-assessment questionnaire. The right side shows the distribution of students' abilities, while the left side shows the difficulty level of items on the same logit scale.

On the right side of the Wright Map, students with codes 18L, 21L, and 49L are at the highest logit (+5), indicating that they have the highest tendency to give positive ratings of their collaborative skills. Their position at the top of the map indicates that they consistently agree with almost all statements, thus classifying them as students with very high collaborative skills. Conversely, students such as 37P, 51P, and 68P are at the lowest logit (around -2), indicating that they tend to disagree with most statements, reflecting a low level of collaborative skills.

On the left side of the Wright Map, item Q3 is at the highest logit (+2), indicating that this statement is the most difficult for students to agree with. Only students with high collaborative skills tend to give positive ratings to this item. Conversely, items Q5 and Q9 are at the lowest logit (around 0), meaning that most students, including those with low abilities, tend to agree with these statements. This means that these items are the easiest to agree with.

The distribution between persons and items shows an imbalance. Most students are in the +2 to +5 logit range, while items only cover the 0 to +2 logit range. This indicates that the instrument tends to be too easy for the tested population and not challenging enough for high-ability students. Boone et al. (2014) state that "Wright Maps allow researchers to examine whether items are well-targeted to the population. If persons are above the items, they are likely to succeed; if below, they are likely to struggle." In this context, the majority of students are above most items, so they are likely to succeed in answering those items. As stated by Aviyanti et al. (2024), "When many students surpass the item difficulty level", it is necessary to add more challenging items to expand the measurement spread.

This mapping is important as a basis for evaluating and refining the instrument. As further explained by Boone et al. (2014), "The Wright Map provides a visual tool to evaluate the match between item difficulty and person ability." Therefore, it is recommended to add items with higher difficulty levels so that the instrument can cover the entire spectrum of student abilities, especially those at high logits, making the instrument more representative and valid for use in measuring collaborative skills.

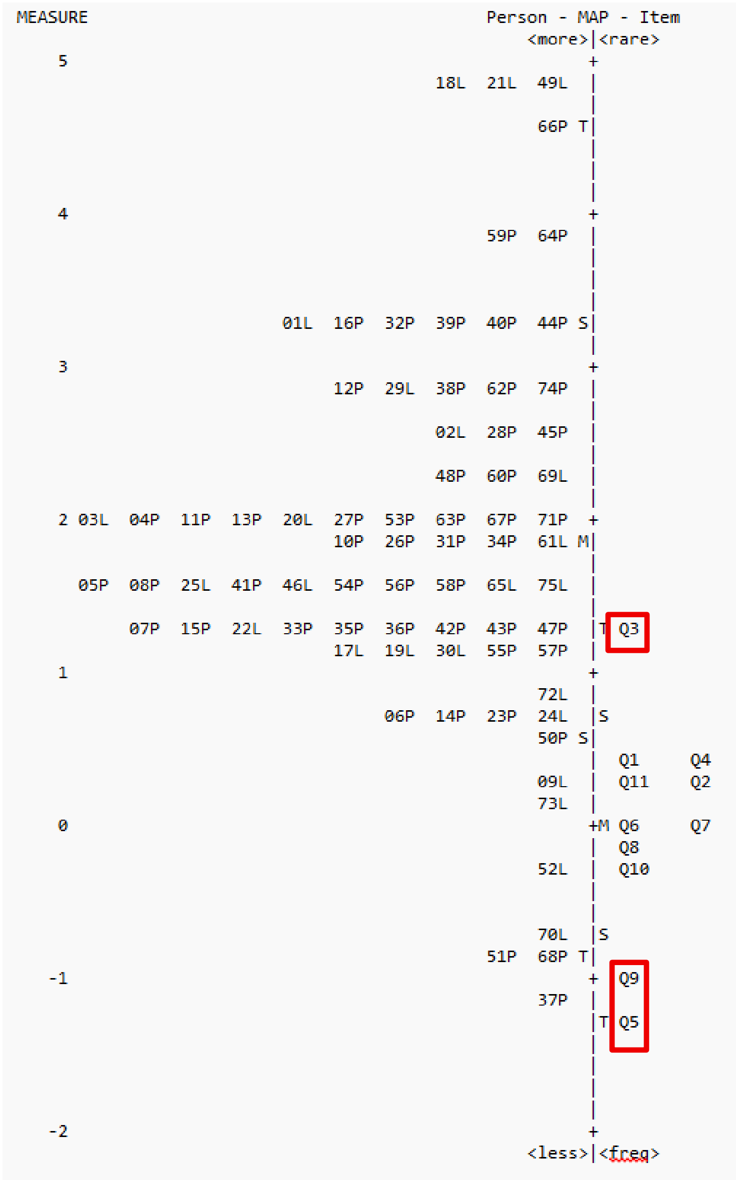

Figure 3. Wright map of person and item collaboratives' self-assessment

Table 10. Logit Level of Difficulty of Collaborative Items

Item Code	Statement	Logit
Q3	I listen carefully to my team's ideas before making a decision	+1,23
Q5	I always show a positive attitude toward the team wherever I am	–1,32

In Rasch analysis, logit values reflect the relative difficulty of an item in relation to the respondent's ability. Item Q3, "I listen carefully to my group's ideas before making a decision," has the highest logit, indicating that this behavior is considered the most difficult for respondents to perform. This can be explained theoretically because actively listening before making a decision involves complex metacognitive and affective skills, such as empathy, self-control, and reflective thinking in a social context. As explained by Boone et al. (2014), "items with higher logit values require a greater level of the latent trait to be endorsed," so Q3 represents advanced collaborative competence (Aviyanti et al., 2024).

Conversely, item Q5, “I always show a positive attitude toward the team wherever I am,” has the lowest logit, meaning that the majority of respondents easily agree with this statement. A positive attitude toward the team is a more common form of social expression and does not require deep cognitive involvement. According to Sumintono & Widhiarso (2013), in the Rasch model, “items with lower difficulty levels have a higher probability of being agreed upon by respondents,” as such behaviors are more accessible and more frequently displayed in everyday social interactions.

Item Q3 (“I listen carefully to my team’s ideas before making a decision”) being the most difficult item, while Q5 (“I always show a positive attitude toward the team wherever I am”) being the easiest, suggests that while positive attitudes are common among students, active listening and integrating others’ ideas into decision-making remain more complex behaviors. Similar results were reported by Voogt et al. (2015), who found that metacognitive and communication-related aspects of collaboration are harder for secondary students to master compared to affective support. Moreover, Strijbos and Fischer (2007) emphasize that listening and negotiating ideas require both cognitive engagement and socio-emotional regulation, which explains their higher difficulty level in self-assessments. Therefore, our findings reinforce the claim by Boone, Staver, and Yale (2014) that Rasch-based item hierarchy not only reflects statistical distribution but also reveals the psychological progression of collaborative competence—from basic affective behaviors to advanced cognitive-social skills.

For items with Point Measure Correlation values below the ideal threshold, such as Q5, revisions can be made by enriching the context of the statement to require a more complex behavioral response. For example, changing from “demonstrates a positive attitude toward the team” to “demonstrates a positive attitude toward the team through constructive feedback when dealing with differences of opinion.” This change will improve the item's discrimination against students with high collaboration skills.

The difference in logits between Q3 and Q5 indicates that the instrument is capable of ranking items based on the complexity of the collaborative behaviors being measured. This aligns with the fundamental principle of Rasch that “the model simultaneously ranks items from most difficult to easiest and persons from highest to lowest ability” (Boone et al., 2014). Thus, the highest and lowest logits are not merely statistical numbers but also reflect the psychological hierarchy of collaborative skills measured by the instrument.

Distribution of collaborative scores in the interpersonal and intrapersonal domains

Based on the analysis results, the average collaborative skill score of students in the interpersonal domain reached 77.5%, while in the intrapersonal domain it reached 82.9%. This difference indicates that students tend to be stronger in self-management aspects (intrapersonal) compared to social and group interaction aspects (interpersonal). This difference in scores can also be attributed to the psychosocial development of high school students, who are in the process of forming their identity and are more comfortable regulating themselves than managing complex social interactions. This pattern is consistent with Hendrawati et al. (2024), who found that improvements in collaboration through project-based learning tend to appear first in intrapersonal aspects before interpersonal interaction develops. Similarly, Gillies (2016) emphasizes that while students can manage their own responsibilities relatively early, effective group communication requires structured facilitation and extended practice. Our results also align with Aviyanti et al. (2024), who reported that cooperative learning settings often enhance self-motivation and task management, while communication and consensus-building remain challenging. This also aligns with Erikson's theory (1968) and Hofstede's findings (2010) that in collectivist cultural contexts like Indonesia, students often demonstrate compliance and good individual performance but require additional facilitation to communicate assertively, express ideas openly, and manage group dynamics. Besides that, according to Howard Gardner's theory of multiple intelligences, intrapersonal intelligence (the ability to understand oneself, regulate emotions, and reflect) differs from interpersonal intelligence (the ability to understand others and interact socially). These findings highlight the developmental nature of collaborative competence and indicate that targeted instructional strategies, such as role rotation and conflict-resolution tasks, may be necessary to strengthen interpersonal collaboration.

This supports the finding that students show a dominance of intrapersonal over interpersonal intelligence in the context of Project-Based Learning collaboration. This also aligns with the finding of Aviyanti et al. (2024) that "Cooperative learning tended to produce greater improvement in self-regulation and individual motivation, while social communication skills required additional support". Therefore, learning interventions involving role rotation, constructive conflict simulation, and two-way communication exercises will be highly beneficial in balancing mastery of both domains.

The interpersonal domain in this study includes indicators such as sharing ideas and information, collaborative problem-solving, supporting team members, awareness of team dynamics, and the ability to interact with others. The score of 77.5% in this domain indicates that most students have demonstrated good ability in collaborating and supporting group members. However, aspects such as open communication, initiative in sharing ideas, and awareness of group dynamics may still need improvement to achieve optimal levels.

Meanwhile, the intrapersonal domain includes indicators such as self-reflection, role flexibility, time management, quality of contribution to the team, and active participation. A score of 82.9% in this domain shows that students are quite skilled at managing themselves while working in groups, for example, by actively participating, adapting to the needs of the team, and showing responsibility for the group's work results.

Furthermore, the distribution of total collaborative skill scores shows that most students (66.67%) fall into the "Collaboration has been established" category, meaning they have demonstrated consistency in contributing effectively to teamwork. A total of 28% of students are in the "Collaboration is developing" category, indicating that they still need further facilitation to refine their collaborative processes. Meanwhile, 5.33% of students are still at the "Collaboration is emerging" stage, indicating the need for more intensive guidance to build basic collaboration skills.

These results show that the intrapersonal dimension contributes significantly to overall collaboration success. However, there is still a need for strengthening higher in the interpersonal aspect, particularly in terms of two-way communication, participation in problem-solving, and team support. Group-based learning interventions involving structured reflection and dynamic roles within the team can be a strategy to balance mastery of both domains.

Table 11. Interpretation of collaborative skills

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%

Results of open-ended questions

In addition to the Likert scale assessment, this instrument also includes three open-ended questions to analyze students' reflections qualitatively. These questions include:
1) What did you learn about yourself after completing the self-assessment sheet?
2) What skills do you want to improve?
3) What small things can you do tomorrow to start improving collaboration?
In general, students' answers show increased self-awareness, especially in terms of personal strengths and weaknesses in collaboration. Many students acknowledge that they are not yet optimal in listening to group opinions (reinforcing the quantitative findings on item Q3) and want to improve this ability. Additionally, students also mentioned concrete actions such as "respecting peers' opinions," "reducing ego," and "being bold in asking questions during discussions" as initial steps to enhance collaboration.

These qualitative findings enrich the quantitative results by providing a deeper narrative context for students' perceptions and intentions for behavioral change. In response to the first open-ended question, three key themes emerged. Students demonstrated a growing awareness of their strengths and weaknesses in collaborative settings, for instance, realizing that they were not fully engaged in listening, lacked active participation in discussions, or tended to remain passive within group activities. This awareness extended to recognizing their roles and personal contributions, such as acknowledging a tendency to wait for instructions rather than taking initiative. Importantly, many students expressed a strong desire to grow, as reflected in statements like "I feel I need to learn more" or "I now realize I need to be more open." These responses suggest that the reflection component of the self-assessment instrument successfully encouraged honest self-evaluation and brought to light aspects of group dynamics that students had previously overlooked.

The second question guided students to identify specific collaborative skills they wished to improve. Analysis of the responses revealed three primary focus areas: interpersonal communication skills, including active listening, confidently expressing opinions, and openly sharing ideas; emotional regulation and collaborative attitudes, such as managing ego, increasing tolerance, and becoming more patient and respectful; and initiative and active participation, including the willingness to initiate discussions, ask questions, and offer help to teammates. These areas align closely with the quantitative findings related to group participation and communication, thereby reinforcing the construct validity of the assessment instrument.

The third question, which was prospective in nature, prompted students to propose small, actionable steps they could take immediately to enhance collaboration. From the 75 responses analyzed, six recurring themes were identified: improving communication and social interaction, such as chatting or greeting peers; practicing mutual respect and attentive listening; engaging in self-reflection and personal development; coordinating and fairly distributing tasks;

providing emotional support and encouragement; and participating in informal social activities like inviting peers to play or waking up early together. The frequency and variety of these proposed actions indicate that students view collaboration not merely as a task-oriented endeavor but as an interpersonal process requiring empathy, mutual support, and proactive engagement.

The high frequency of themes related to communication and mutual appreciation among members indicates that students view cooperation as an interpersonal process, not merely an academic task. These small actions are also realistic and demonstrate their readiness to make gradual behavioral changes.

This qualitative reflection confirms that students not only recognize their weaknesses in cooperation but are also able to identify specific skills they wish to develop and concrete actions they can take immediately. This aspect enriches the quantitative findings and demonstrates the effectiveness of the instrument in stimulating students' social metacognition. Thus, these three open-ended questions can be recommended as an important part of formative assessment of student collaboration.

These findings confirm that the integration of Rasch-based self-assessment in PBL not only functions as a measurement tool but also as a learning intervention that triggers self-reflection, role awareness, and improvement of students' collaboration strategies. Going forward, teachers can utilize this instrument as part of ongoing formative assessment, with a cycle of reflection–improvement–evaluation repeated in each project, so that collaboration skills develop consistently and measurably.

CONCLUSION

This study affirms that the collaborative self-assessment instrument used is of good quality in measuring students' collaborative skills within the context of renewable energy project-based learning. The instrument has been proven to be valid and reliable through Rasch model analysis, and the instrument effectively distinguishes varying levels of collaborative ability among students. Notably, most students demonstrate stronger intrapersonal skills than interpersonal ones, with the majority classified as possessing well-established collaborative skills. Reflective responses further highlight a deep sense of self-awareness, a genuine eagerness for growth, and a dedicated commitment to enhancing teamwork. These findings emphasize the importance of incorporating self-assessment as part of learning strategies to foster reflection, responsibility, and the development of 21st-century skills, especially collaboration. However, adjustments to more challenging items are recommended to enhance the instrument's measurement capacity for students with higher abilities.

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