Jurnal Pendidikan Fisika

Vol. 15 No. 1, Juni 2026_11-123
DOI: 10.24114/4kxt6r75
p-ISSN: 2552-732X
e-ISSN: 2301-7651

Research Article

OPEN ACCESS

The Effect of a PBL Interactive Physics Module on Student's Collaboration Skills Based on Learning Styles

[1]Putri Anggaraeni*, [2]Muhammad Arsyad,[3]Abdul Haris

[1] Master of Physics Education, Universitas Negeri Makassar, Jl. Daeng Tata Raya, Kampus Parangtambung, Indonesia

ARTICLE INFO

Article History:
Submitted: 26-04-2026
Revised : 16-05-2026
Accepted : 09-06-2026
Published: 29-06-2026

Keywords:
Collaboration Skills;
Interactive Physics Module;
Learning Styles;
Problem Based Learning

Kata Kunci:
Keterampilan Kolaborasi;
Modul Fisika Interaktif;
Gaya Belajar;
Pembelajaran Berbasis Masalah

ABSTRACT

This study was conducted based on the problem of low students' collaboration skills in physics education at one of the senior high schools in Makassar and the need for innovative teaching materials that support active learning. The study aimed to analyze the effect of a PBL interactive physics module on students' collaboration ability in terms of learning styles. This study used a quantitative approach based on a quasi experimental design. This investigation subjects consisted of an experimental class that received instruction using a PBL based interactive physics module and a control class that received instruction without the PBL interactive physics module. Data were collected through a learning style questionnaire, a collaboration skills observation sheet, and documentation. Data analysis was conducted using a two way analysis of variance (ANOVA). The analysis revealed that the utilization of the PBL interactive physics module had a significant influence on students' collaboration skills. Learning styles also had a significant influence on students' collaboration skills. However, the interaction between the utilization of the PBL interactive physics module and learning styles did not have a significant influence on students' collaboration skills. The results suggest that the PBL interactive physics module is effective in developing students' collaboration skills in physics education. Therefore, the implementation of PBL based interactive modules is recommended as an alternative instructional strategy to promote active learning and enhance collaboration skills in physics learning more broadly.

ABSTRAK

Penelitian ini dilakukan berdasarkan permasalahan rendahnya kemampuan kolaborasi siswa dalam pendidikan fisika di salah satu SMA di Makassar dan kebutuhan akan bahan ajar inovatif yang mendukung pembelajaran aktif. Penelitian ini bertujuan untuk menganalisis pengaruh modul fisika interaktif PBL terhadap kemampuan kolaborasi siswa dalam hal gaya belajar. Penelitian ini menggunakan pendekatan kuantitatif berdasarkan desain kuasi eksperimental. Subjek penelitian ini terdiri dari kelas eksperimen yang menerima pengajaran menggunakan modul fisika interaktif berbasis PBL dan kelas kontrol yang menerima pengajaran tanpa modul fisika interaktif PBL. Data dikumpulkan melalui kuesioner gaya belajar, lembar observasi kemampuan kolaborasi, dan dokumentasi. Analisis data dilakukan menggunakan analisis varians dua arah (ANOVA). Analisis menunjukkan bahwa penggunaan modul fisika interaktif PBL berpengaruh signifikan terhadap kemampuan kolaborasi siswa. Gaya belajar juga berpengaruh signifikan terhadap kemampuan kolaborasi siswa. Namun, interaksi antara penggunaan modul fisika interaktif PBL dan gaya belajar tidak berpengaruh signifikan terhadap kemampuan kolaborasi siswa. Hasil penelitian menunjukkan bahwa modul fisika interaktif PBL efektif dalam mengembangkan kemampuan kolaborasi siswa dalam pendidikan fisika. Oleh karena itu, implementasi modul interaktif berbasis PBL direkomendasikan sebagai strategi pembelajaran alternatif untuk mendorong pembelajaran aktif dan meningkatkan keterampilan kolaborasi dalam pembelajaran fisika secara lebih luas.

*Corresponding Author
Email: putrianggaraeni.s22024@student.unm.ac.id

INTRODUCTION

Education in the era of globalization is essential in preparing individuals to adapt to the fast paced progress of scientific progress, technological advancement, and the growing complexity demands of modern life. Within the context of 21st century learning, in addition to gaining academic knowledge, students are expected to develop various essential skills that support their academic performance and social competence. The core competencies of the 21st century include critical thinking, collaboration, communication, and creativity (Schunk, 2020). Among these, collaboration has become one of the most important skills to be fostered in classroom practice. Collaboration skills refer to students' ability to cooperate effectively with others, exchange ideas, respect the contributions of group members, and complete tasks collectively to accomplish common learning objectives.

Johnson and Johnson (2009) emphasize that effective collaboration is built upon five essential components, namely mutual dependence, individual responsibility, mutually supportive direct interaction, interpersonal capabilities, and group self assessment. In physics education, collaboration is particularly important because learning activities often involve group discussions, experiments, as well as problem solving activities that encourage students to integrate conceptual understanding with practical application. For this reason, collaboration skills should be intentionally cultivated in physics classrooms. However, in practice, students' collaboration skills are often still underdeveloped. Previous studies have shown that collaborative learning environments significantly improve students' social interaction and teamwork abilities (Pulgar et al., 2020; Hoehn et al., 2020; Zhou, 2024). This can be observed during group assignments, where some students tend to engage in off task behavior, such as chatting or playing, show limited teamwork, and rely on only one or two active members to complete the task. In some cases, groups fail to complete the assigned work altogether. This evidence is consistent with previous studies by Nurwahidah et al. (2021), who reported that students' collaboration skills in classroom learning had not yet developed optimally. Similarly, previous studies in physics education have shown that learning approaches emphasizing active participation and group work can significantly enhance students' collaboration skills and engagement in learning processes (Nicholus et al, 2023).

Previous studies have explored various instructional strategies to enhance student engagement and academic achievement in physics education. In physics education, the utilization of Problem Based Learning (PBL) has been proven to foster students' conceptual understanding and higher order thinking skills (Ayu et al., 2024; Gumisirizah et al., 2023). Problem Based Learning (PBL) refers to a student centered instructional approach where learners engage in solving authentic problems in small groups under the guidance of a facilitator, aiming to develop both conceptual understanding and problem solving competencies. This approach supports students to actively construct knowledge through real world problem solving activities. Furthermore, Problem Based Learning (PBL) is regarded as an instructional model that enables students to develop analytical thinking skills through active engagement in solving physics problems, either individually or in collaborative groups (Nirwana et al., 2021). PBL has been generally implemented as a student focused approach that supports active learning, inquiry, and collaboration, leading to improvements in both deep conceptual understanding and advanced cognitive skills (Arends, 2012). PBL is also considered an effective student centered approach that encourages active learning while strengthening critical thinking and problem solving skills (Anggraeni et al, 2023; Liu, 2022). Furthermore, PBL facilitates collaborative learning through group based problem solving activities (Sepúlveda et al., 2021). Haris et al. (2024) implemented a Dynamic Problem Solving strategy that actively engaged students in analyzing and solving physics related problems, thereby making the learning process more interactive and meaningful. The strategy encouraged students to participate in discussions, exchange ideas, and work collaboratively to solve physics problems. These findings suggest that problem based learning approaches have strong potential to foster the development of students' collaboration skills in physics education.

Physics learning modules are one of the effective learning resources that help students understand physics concepts while simultaneously developing higher order thinking skills (Ahmad et al., 2021). Anugra et al. (2025) stated that the use of digital teaching materials can improve the effectiveness of physics learning and support students' engagement in the learning process. Recent studies have shown that the utilize of interactive learning media, particularly digital and multimedia based modules, can improve students' motivation, engagement, conceptual understanding, and learning outcomes by presenting learning materials in a more structured and interactive manner (Tarigan et al., 2023). Interactive physics modules provide multimedia features such as animations, videos, simulations, and quizzes that support students in understanding abstract physics concepts while accommodating different learning preferences (Dewi & Nisa', 2025). The interactive physics module used in this study was developed in a digital flipbook format, allowing students to access learning materials, multimedia content, and interactive activities in an organized and user friendly interface. The integration of interactive modules with instructional approaches such as PBL also encourages active participation, inquiry, discussion, and shared responsibility among students during the learning process. In addition, previous findings indicate that interactive digital modules contribute not only to students' academic performance and memory retention but also to more meaningful and collaborative learning experiences (Wu et al., 2024). These studies suggest that the combination of effective instructional models and interactive learning media plays an important role in supporting the development of collaboration skills through structured social learning activities.

One factor contributing to the low level of students' collaboration ability is the use of instructional models that are not sufficiently aligned with the development of such competencies. In addition to instructional design, individual learner characteristics, including learning styles, should also be considered in the instructional process. Learning style refers to how learner receive, process, and use information during learning activities (Nasution, 2015). Nevertheless, classroom observations indicate that many students are still unaware of their dominant learning styles. In fact, an understanding of learning styles is important not only for helping students optimize their learning process but also for assisting teachers in selecting appropriate learning resources and instructional strategies (Zahra and Iryana, 2024). Students with visual learning styles tend to participate more actively when collaborative physics learning activities involve diagrams, animations, simulations, or visual representations of concepts. Auditory learners are generally more engaged through verbal explanations and group discussions, whereas kinesthetic learners tend to collaborate more effectively through experiments, hands on activities, and direct involvement in problem solving tasks in physics learning (Yulianci et al., 2020 ; Puri & Perdana, 2022). Therefore, the selection of teaching models and learning materials that take students' learning styles into account is expected to contribute to the improvement of collaboration skills.

One possible approach to accommodating diverse learning styles is the integration of the PBL model with interactive physics modules. PBL is an instructional model that involves students in problem solving activities through scientific inquiry, thereby enabling them to acquire knowledge while simultaneously developing problem solving skills, both individually and collaboratively (Arends, 2012). In PBL, students act as central agents in the learning process, reflecting a student centered approach. Through engagement in problem solving and inquiry activities, students actively construct knowledge while developing higher order thinking skills, collaboration, communication, and teamwork, leading to more meaningful learning outcomes (Sepúlveda et al., 2021). This perspective is consistent with the five major phases of PBL proposed by Arends (2012), familiarizing students with the problem, structuring students' learning activities, facilitating the investigation process, preparing and presenting their work, and reflecting on the problem solving process.Through these stages, PBL encourages students to participate actively in discussion, questioning, explanation, and the expression of ideas. As a result, this model has strong potential to create a collaborative learning environment.

However, despite the extensive use of Problem Based Learning with interactive modules in physics educational process, most previous studies primarily focus on improving students' cognitive outcomes and conceptual understanding. Research that specifically examines collaboration skills is still limited and often does not consider individual learner characteristics, such as learning styles. Furthermore, studies integrating Problem Based Learning, interactive modules, and learning styles within a single framework to enhance collaboration skills remain scarce. Therefore, there is a need for research that comprehensively examines the combined effect of instructional models, interactive learning media, and student characteristics in order to optimize the development of collaboration skills. Based on the foregoing considerations, this research was conducted to investigate the effect of Problem Based Learning based interactive physics to improving students' collaboration skills in relation to their learning styles.

METHODS

The present study used a quantitative approach in a quasi experimental design and a factorial structure. Specifically, a 2 × 3 factorial design was employed, where the first factor involved the implementation of interactive physics modules based on PBL (with and without interactive modules), while the second factor consisted of students' learning styles, classified as visual, auditory, and kinesthetic.

The research was carried out at one of the senior high schools in Makassar, South Sulawesi, Indonesia, with tenth grade students enrolled in the second semester of the 2025/2026 school year. The sample consisted of four classes selected using a cluster random sampling technique, including two experimental classes and two control classes. Students in the experimental groups received instruction using interactive physics modules based on PBL, whereas those in the control groups were taught without the use of interactive physics modules based on PBL.

Data were collected using a learning style questionnaire and a collaboration skills questionnaire. The learning style questionnaire was used to classify students into three categories into three learning style categories: visual, auditory, and kinesthetic. Meanwhile, the collaboration skills questionnaire was used to assess the collaborative skills among students are described in five points: (1) mutual support, (2) taking responsibility, (3) encouraging future relationships, (4) social skills, and (5) the ability to work in a group. Both instruments utilized a Likert scale from 1 to 4. The instrument was constructed using a blueprint as shown in Table 1

Table 1. Blueprint of the Collaboration Skills Instrument

No	Indicator	Sub-Indicator	Item Number
1	Mutual Support	Dependence on group members	1, 2 , 3
		Importance of each member's role	4
		Need for peer assistance	5
Total Indicator 1			1-5
2	Taking responsibility	Completing individual tasks	6, 10
		Sharing understanding	7
		Responsibility for opinions	8, 9
Total Indicator 2			6-10
3	Encouraging future relationships	Participation in discussion	11
		Responding to peers' ideas	12
		Information exchange	13
		Expressing ideas orally	14
		Asking questions	15
Total Indicator 3			11-15
4	Social skills	Listening skills	16, 19
		Maintaining good attitude	17
		Respecting others	18

No	Indicator	Sub-Indicator	Item Number
		Polite communication	20
Total Indicator 4			16 – 20
5	The ability to work in a group	Evaluating group solutions	21, 22
		Drawing conclusions	23, 25
		Reflection and improvement	24
Total Indicator 5			21 – 25
Grand Total			1 - 25

The data were processed through both descriptive and hypothetical statistical analyses. Descriptive statistics were employed to present an overview of students' collaboration skills. Inferential analysis was carried out through assumption tests, including tests of normality and homogeneity of variance, followed by a two way ANOVA. This analysis was performed to investigate the influence of using interactive physics modules based on PBL, learning styles, and the interaction effect between the two variables on students' collaboration skills. To ensure the validity, feasibility, and reliability of the developed product and research instruments, this investigation conducted a series of analyses, including product feasibility analysis, instrument validation, and statistical analysis of the collected data. Instrument validation is essential to ensure that the data collected accurately represent the variables being measured (Lina & Desnita, 2022).

1. Product Feasibility Analysis

Product feasibility analysis evaluates whether the learning module is practical and suitable for implementation in the educational setting. According to Wiyoko (2019), feasibility analysis involves examining the content, design, language, and instructional strategy of the product to ensure alignment with instructional objectives and user requirements. In the context of interactive physics modules based on PBL, this analysis considers factors such as clarity of explanations, appropriateness of problems, integration of collaborative activities, and compatibility with various learning styles.

The feasibility assessment is generally conducted using expert evaluation with a Likert scale, typically ranging from 1 (very poor) to 4 (very good). The results are categorized using a feasibility interval table as shown below.

Table 2. Product Feasibility Interval (Widoyoko, 2017)

Interval	Score	Category
$3.25 < \bar{X} \leq 4.00$	76% - 100%	Very Feasible
$2.50 < \bar{X} \leq 3.25$	51% - 75%	Feasible
$1.75 < \bar{X} \leq 2.50$	26% - 50%	Not Feasible
$1.00 < \bar{X} \leq 1.75$	0% - 25%	Very Not Feasible

A module is considered feasible for classroom use if the average score falls within the "Feasible" or "Very Feasible" range.

2. Instrument Validation Analysis

Instrument validation ensures that the tools used in the study accurately measure the intended constructs. Validity can be categorized into content validity, construct validity, and empirical validity (Sugiyono, 2011).

Content and Construct Validity: These were examined using expert judgment involving three experts, involving physics educators, instructional media specialists, and learning experts. Experts assessed the module's alignment with learning objectives, PBL syntax, and collaborative activities using a four point Likert scale. Aiken's V coefficient was employed to evaluate content validity, with a score of ≥ 0.60 indicating a valid item.

Table 3. Aiken's V Validity Criteria

Aiken's V	Validity Level
$0.81 < V \leq 1.00$	Very High
$0.61 < V \leq 0.80$	High
$0.41 < V \leq 0.60$	Moderate
$0.21 < V \leq 0.40$	Low
$0.00 < V \leq 0.20$	Very Low

Empirical Validity: For questionnaires measuring collaboration skills and learning styles, a pilot test was conducted with students outside the study sample. Pearson's product moment correlation formula was used to analyze the relationship between each item and the overall score. Items with $r_{hitung} > r_{tabel}$ at $\alpha = 0.05$ were considered valid.

Table 4. Pearson Correlation Validity Criteria

r value	Validity Level
0.81 < V ≤ 1.00	Very High
0.61 < V ≤ 0.80	High
0.41 < V ≤ 0.60	Moderate
0.21 < V ≤ 0.40	Low
0.00 < V ≤ 0.20	Very Low

In addition to validity testing, reliability testing was also conducted to determine the consistency and stability of the research instruments. Reliability refers to the extent to which an instrument produces consistent results when administered under similar conditions. In this study, instrument reliability was measured using Cronbach's Alpha coefficient with the assistance of IBM SPSS. An instrument was considered reliable if the Cronbach's Alpha value exceeded 0.70, indicating that the instrument had an acceptable level of internal consistency before being applied in the research process.

3. Analys of Collected Data

All collected data were processed with IBM SPSS Statistics 26. Prior to inferential analysis, the data were examined for normality and homogeneity of variance to ensure that parametric statistical tests could be appropriately applied. The Shapiro–Wilk test was employed to measure the normality of collaboration skills scores, while Levene's test was utilized to verify the homogeneity of variances between experimental and control class. Data were considered normally distributed if the significance level exceeded 0.05 ($p > 0.05$) and variances were considered homogeneous if Levene's test yielded $p > 0.05$.

A general statistical method is provided, which includes average values and standard deviations, among other things of students' collaboration skills across both experimental and control groups, as well as among different learning style categories (visual, auditory, and kinesthetic). This allowed for a preliminary understanding of data trends and potential differences between groups.

For inferential analysis, a two way ANOVA was carried out in order to assess the impact of the PBL interactive physics module, learning styles, and their interaction on students' collaboration skills. The statistical significance level was set at 0.05. This approach enabled the researchers to determine not only the main effects of the intervention and learning styles but also whether the effectiveness of the module varied across different learning style groups.

RESULTS AND DISCUSSION

This present section describes the study results of the study and presents a discussion of the findings in accordance with the research objectives. The analysis covers product feasibility, instrument validation, and hypothesis testing related to the implementation of interactive physics modules based on PBL and students' learning styles on collaboration skills. The discussion begins with the results of instrument validation to confirm the validity of the data used in this research. The results of the Aiken's V index, derived from expert evaluations of the interactive physics module based on PBL, are presented in Table 5.

Table 5. Validation Results of the Interactive Physics Module Based on Problem Based Learning

No	Assessed Aspect	Aiken's V Value	Criteria
1	Alignment of the material with the curriculum and learning outcomes	0.83	Very High
2	Accuracy of physics concepts	0.67	High
3	Suitability of the material with students' developmental level	0.83	Very High
4	Depth and breadth of energy related content	0.67	High
5	Relevance of the material to daily life	1.00	Very High
6	Presentation of contextual problems at the beginning of learning	0.67	High
7	Problems encourage critical and analytical thinking	0.83	Very High
8	PBL steps are presented systematically and clearly	0.83	Very High

No	Assessed Aspect	Aiken's V Value	Criteria
9	The module facilitates discussion and group work	1.00	Very High
10	The module encourages students to find solutions	0.83	Very High
11	The module provides interactive features (buttons, videos, animations, and quizzes)	0.83	Very High
12	User interaction with the module is easy to perform	0.83	Very High
13	The module provides feedback on students' activities	0.83	Very High
14	Interactivity supports understanding of renewable energy concepts	0.83	Very High
15	The module is engaging and not monotonous	0.83	Very High
16	Language complies with standard Indonesian grammar rules	0.83	Very High
17	Sentences are easy for students to understand	0.83	Very High
18	Physics terminology is used appropriately	0.83	Very High
19	Instructions for using the module are clear	0.83	Very High
20	Language encourages students' learning motivation	0.83	Very High
21	Layout is neat and well organized	1.00	Very High
22	Color and font selection are comfortable to read	1.00	Very High
23	Images and illustrations support the material	0.83	Very High
24	Module navigation is easy to use	0.83	Very High
25	Overall appearance of the module is attractive and proportional	1.00	Very High
Average		0.85	Very High

Based on the data in Table 5, all assessed aspects achieved Aiken's V values ranging from high to very high categories. The overall average score of 0.85 indicates that the developed module demonstrates a very high level of content validity. Therefore, the interactive physics module is considered valid and suitable for implementation in the learning process.

The validity of the collaborative skills instrument was tested using the SPSS program with the pearson product moment correlation technique. This test was conducted to examine the relationship between the score of each item and the total score, as indicated by the corrected item total correlation value.

Based on the validity test results with a sample of 22 respondents, the critical value of $r_{table} = 0.423$ was obtained at a significance level of $\alpha = 0.05$. An item is considered valid if the calculated correlation coefficient (r_{count}) exceeds the critical value (r_{table}). The results of the validity test for the collaboration skills instrument are presented in Table 6

Table 6. Validity Test Results of the Collaboration Skills Instrument Using Pearson Product Moment Correlation Technique

No	Item Code	r_{count}	r_{table}	Description
1	P1	0.659	0.423	Valid
2	P2	0.513	0.423	Valid
3	P3	0.758	0.423	Valid
4	P4	0.832	0.423	Valid
5	P5	0.814	0.423	Valid
6	P6	0.818	0.423	Valid
7	P7	0.817	0423	Valid
8	P8	0.727	0.423	Valid
9	P9	0.806	0.423	Valid
10	P10	0.712	0.423	Valid
11	P11	0.789	0.423	Valid
12	P12	0.782	0.423	Valid
13	P13	0.693	0.423	Valid
14	P14	0.803	0.423	Valid
15	P15	0.746	0.423	Valid
16	P16	0.715	0.423	Valid
17	P17	0.770	0.423	Valid
18	P18	0.670	0.423	Valid
19	P19	0.769	0.423	Valid
20	P20	0.752	0.423	Valid
21	P21	0.793	0.423	Valid
22	P22	0.741	0.423	Valid
23	P23	0.688	0.423	Valid
24	P24	0.618	0.423	Valid
25	P25	0.748	0.423	Valid

Based on Table 6, all items have corrected item total correlation values higher than the critical value of $r_{table} = 0.423$. Therefore, all items are regarded as valid and suitable for use in the main study. These results indicate that the instrument has good construct validity and can reliably measure students' collaboration skills
The reliability of the collaboration skills instrument was analyzed using Cronbach's Alpha with the assistance of SPSS. This test was carried out to evaluate the internal consistency of the instrument in measuring students' collaboration skills.

Based on the analysis results, the Cronbach's Alpha coefficient obtained was 0.96. According to the reliability criteria, An instrument is judged reliable if the Cronbach's Alpha exceeds 0.70. Therefore, the obtained value provides evidence of the instrument's high reliability. This result shows that the collaboration skills questionnaire is consistent and reliable in measuring the intended construct. Thus, all items in the instrument can be used for further data collection in the main study.

Descriptive and inferential statistical analyses are used to present the findings of this study in relation to the research objectives, namely to investigate the effect of interactive physics modules based on PBL on students' collaboration skills in relation to their learning styles.

Before conducting hypothesis testing, the analysis began with a descriptive approach to present a general description of students' collaboration skills across the experimental and control groups. This analysis was intended to identify the tendency of differences in the mean collaboration skill scores between students who learned through interactive physics modules based on PBL and those who learned without the use of such modules. The descriptive statistical results of students' collaboration skills in both groups are presented in Table 7.

Table 7. Descriptive Data on Students' Collaboration Skills

Class	N	Mean	Standar Deviation
Experimental	52	80.54	7.16
control	61	66.84	9.07

The descriptive analysis presented in Table 7 indicates that students who learned using the PBL based interactive physics modules demonstrated better collaboration skills compared to those who learned without the modules. This finding suggests that the integration of PBL with interactive learning modules may create more active and collaborative learning environments, allowing students to participate more effectively in group discussions, problem solving activities, and shared learning tasks.

When analyzed based on learning styles, the mean scores of students' collaboration skills among students categorized as visual, auditory, and kinesthetic learners also showed differences across the three groups, as presented in Table 8.

Table 8. Mean Scores of Students' Collaboration Skills by Learning Style

Learning Style	Class	N	Mean	SD
Visual	Experimental	6	75.67	6.15
	Control	17	62.47	6.53
Auditory	Exsperimental	23	79.13	6.43
	Control	28	67.67	9.65
Kinesthetic	Exsperimental	23	83.22	7.28
	Control	23	69.33	9.33

As presented in Table 8, students in the experimental class consistently demonstrated higher collaboration skills across all learning style categories compared to those in the control class. Among the three learning styles, students with kinesthetic tendencies appeared to show the strongest collaboration performance, followed by auditory and visual learners. These descriptive findings suggest that learning styles may influence the way students participate and interact during collaborative learning activities, particularly in learning environments supported by PBL based interactive modules. Therefore, further inferential analysis was conducted to examine the significance of these differences.

Prior to hypothesis testing using two way ANOVA, prerequisite tests were first conducted, including the normality test and the homogeneity of variance test. A normality test was performed to assess whether the data on students' collaboration skills were normally distributed, while a homogeneity test was conducted to examine if the variances among the comparison groups were equal. These assumptions must be met to support the appropriate implementation of two way ANOVA. The test results for the prerequisite analyses are shown in Table 9.

Table 9. Test Results of the Prerequisite

Test	Class	Sig	Interpretation
Normality (*Shapiro – Wilk*)	Exsperimental	0.11	Normal
	Control	0.16	Normal
Homogeneity (*Levene's Test*)	Overall	0.23	Homogeneous

Based on Table 9, the findings from the normality assessment of students' collaboration skills data by group, analyzed using IBM SPSS Statistics, showed that the significance level for the experimental group reached 0.111, whereas the control group recorded 0.158. As both significance levels exceeded 0.05 ($p > 0.05$), the obtained data on students' collaboration skills in both groups were regarded as normally distributed. In addition, Levene's test for homogeneity of variance produced a significance value of 0.227, which also exceeded 0.05 ($p > 0.05$). This suggests that the variances across the comparison groups were homogeneous. Since both prerequisite assumptions were met, the dataset was considered appropriate for further analysis using two way ANOVA.

After confirming that the data met the required assumptions, hypothesis testing was conducted using two way ANOVA to examine the effect of PBL based interactive physics modules, the effect of learning styles, as well as the interaction between these two factors on students' collaboration skills. This analysis was used to address the research questions from an inferential perspective. Table 10 presents the results of the two way ANOVA.

Table 10. Results of the Two Way ANOVA

Source of Variation	F	Sig.	Interpretation
Problem Based Learning Based Interactive Physics Module	56.66	<0.01	Significant
Learning Style	5.42	0.006	Significant
Interaction between Module and Learning Style	0.27	0.760	Not Significant

Based on Table 10, the two way ANOVA findings showed that the class factor had a significant influence on students' collaboration skills, with a significance level of $p < 0.01$, indicating that it was below the 0.05 criterion. This result confirms a significant difference in the average collaboration skill scores between the experimental group, which learned through interactive physics modules based on PBL, and the control group, which learned without such modules. Students in the experimental group demonstrated higher collaboration skills than students in the control group. This suggests that the implementation of interactive physics modules based on PBL proved effective in enhancing students' collaboration skills. This outcome may be attributed to the characteristics of PBL, which promote students' active involvement in solving problems through discussion, task sharing, idea exchange, and collective responsibility within groups. In addition, the interactive module delivers learning materials in a more engaging way and encourages greater student participation throughout the instructional process. Therefore, the combination of the PBL model and the interactive module not only supports students comprehension of physics concepts but also contributes to the improvement of their collaborative skills. The findings of this study indicate that the use of PBL based interactive modules significantly improves students' collaboration skills. This result is consistent with previous studies showing that PBL enhances teamwork, active participation, and communication skills (Maruf & Mawardi, 2023; Putri, 2023). These findings are also supported by previous research indicating that collaborative learning environments foster shared responsibility and interaction among students (Hoehn et al., 2020). In addition, the use of interactive modules supports student engagement by providing structured guidance and interactive features, which facilitate more effective collaboration during the learning process (Dewi & Nisa', 2025). In addition to the effect of the instructional model, differences in students' learning styles may also contribute to variations in collaborative behavior. In collaborative classroom environments, such differences may manifest in how actively students contribute to group discussions and problem solving tasks. Similarly, studies by Aprianto et al. (2025) reported that variations in learning styles affect students' collaborative behaviors, particularly in terms of communication, participation, and the effectiveness of teamwork during project based learning activities.

The analysis further revealed that the learning style factor also had a significant influence on students' collaboration skills, with a significance value of $p = 0.006$, which is lower than 0.05. This indicates that collaboration skills differed significantly among students across visual, auditory, and kinesthetic learning style categories. These findings suggest that the variation in collaboration skills was primarily associated with students in the visual learning style group. From a theoretical perspective, this can be understood by considering that students differ in the ways they receive and process information during learning. This finding is consistent with previous research by (Han & Ellis, 2021) indicating that variations in learning styles influence students' interaction patterns, communication behavior, and teamwork effectiveness in collaborative learning environments. In the context of this study, students categorized as visual learners appeared to benefit more from the structured and visually enriched presentation of content provided by the interactive module. In contrast, auditory learners were more effectively supported through collaborative discussion, whereas kinesthetic learners tended to be more engaged through active participation in learning activities. Such differences reflect how learning preferences shape students' engagement and participation in group based learning, ultimately affecting their collaborative performance (Aprianto et al, 2025). Accordingly, learning style can be regarded as one of the factors contributing to variation in students' collaboration skills, although these findings do not imply that one learning style is inherently superior to the others.

In contrast, the interaction effect between class and learning style was found to be not statistically significant, with a significance value of $p = 0.760$ ($p > 0.05$). This indicates that there was no significant interaction between the use of PBL based interactive physics modules and learning style in influencing students' collaboration skills. To further illustrate the interaction effect between learning models and learning styles on students' collaboration skills, an interaction plot is presented in Figure 1.

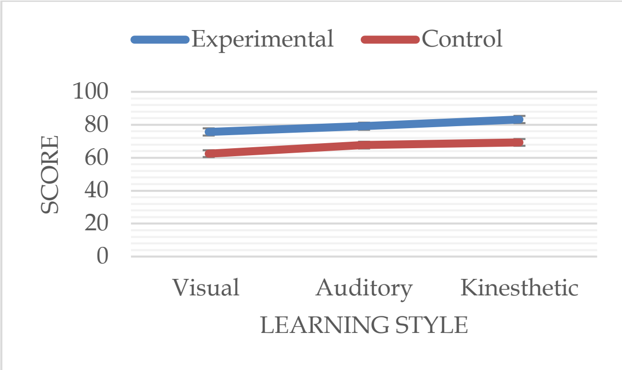

Figure 1. Interaction Plot of Learning Model and Learning Styles on Collaboration Skills

Figure 1 shows that the lines representing the experimental and control groups tend to be relatively parallel without substantial intersection across learning style categories. This pattern supports the ANOVA results, indicating that there was no significant interaction effect between the use of PBL based interactive physics modules and learning styles on students' collaboration skills.

In other words, although students' collaboration skills differed according to both class and learning style, the effectiveness of the treatment did not vary significantly across the different learning style groups. This finding suggests that the PBL approach, which emphasizes problem solving, inquiry, and collaborative activities, is capable of accommodating diverse learning characteristics (Sepúlveda et al, 2021). This also finding suggests that the PBL based interactive module was sufficiently accommodating to the diversity of students' learning characteristics, as it integrates visual elements, collaborative discussion, and problem solving activities.

Furthermore, the use of interactive modules provides structured and engaging learning experiences that support active participation and collaboration among students (Tarigan, 2023). The interactivity provided by the PBL based interactive physics module also appeared to support the development of students' social and collaborative skills during classroom activities. Through the integration of videos, interactive quizzes, and renewable energy related problem scenarios, students were encouraged to exchange ideas, discuss possible solutions, and support one another in completing group tasks. For example, when students analyzed video based problems related to renewable energy applications, group members actively shared explanations, clarified concepts, and assisted peers who experienced difficulties in understanding the material. These interactions reflect the presence of mutual support and positive interdependence among students during collaborative learning activities.

In addition, the use of interactive quizzes within the module stimulated communication and teamwork among students. During group discussions, students collaboratively interpreted questions, compared answers, and negotiated problem solving strategies before reaching conclusions. Such activities encouraged students to practice important social skills, including listening to peers' opinions, respecting different perspectives, providing feedback, and participating actively in group decision making. These findings indicate that the interactive features embedded in the module not only facilitated conceptual understanding but also created learning situations that promoted collaboration and social interaction among students.

Overall, the findings of this study demonstrate that the implementation of interactive physics modules grounded in PBL was effective in enhancing students' collaboration skills, that learning style contributed to differences in collaboration skills, and that learning style did not significantly moderate the effect of the treatment.

CONCLUSION

In conclusion, the results of this research indicate that the implementation of interactive physics modules grounded in PBL significantly improved students' collaboration skills. The analysis also revealed significant differences in collaboration skills across visual, auditory, and kinesthetic learning style categories. However, the interaction between the treatment and learning style was not statistically significant. These results suggest that interactive physics modules grounded in PBL can effectively enhance students' collaboration skills and may be applied to learners with diverse learning style characteristics.

This study has several limitations. First, the research was conducted only in one senior high school with a limited number of participants, which may limit the generalizability of the findings to broader educational contexts. Second, the study focused primarily on students' collaboration skills and learning styles without examining other factors that may influence collaborative learning outcomes, such as learning motivation or technological proficiency.

Therefore, future researchers are recommended to conduct similar studies involving larger and more diverse samples from different educational settings. Further studies may also investigate the effect of PBL based interactive modules on other 21st century skills, such as critical thinking, creativity, or communication skills, as well as explore the integration of more advanced digital learning platforms to support collaborative learning.

REFERENCES

Ahmad, D. W., Arsyad, M., & Helmi. (2021). The development of physics learning module based on creative thinking. Jurnal Pendidikan Fisika, 9(3). https://doi.org/10.26618/jpf.v9i3.5948

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, 49, 101334. https://doi.org/10.1016/j.tsc.2023.101334

Anugra, K. M., Haris, A., & Nurhayati. (2025). Pengembangan bahan ajar fisika secara daring berbasis Google Classroom di SMAN 1 Palopo. Jurnal Sains dan Pendidikan Fisika, 21(2), 175–183.

Aprianto, D., Sutarman, & Syarifaturrahman, W. K. (2025). Exploring the impacts of learning styles on collaboration in project based learning across gender. *Humanitatis Journal of Language and Literature*, 12(1), 41–56. https://doi.org/10.30812/humanitatis.v12i1.5661

Arends, R. I. (2012). *Learning to teach* (9th ed.). Salemba Humanika.

Ayu, H. D., Chusniyah, D. A., Kurniawati, M. P., Purwanti, P. F., Lukitawanti, S. D., & Putri, A. N. (2024). Problem based learning as an effective solution to enhance understanding of physics concepts: A systematic literature review. *Journal of Environment and Sustainability Education*, *2*(2), 86–105. https://doi.org/10.62672/joease.v2i2.29

Dewi, S., & Nisa', K. (2025). Physics learning with the problem based learning (PBL) model based on electronic liveworksheets to improve critical thinking skills. *Journal of Digitalization in Physics Education*. *1(3)*, 1-11. https://doi.org/10.26740/jdpe.v1i3.42583

Haris, A., Hasyim, M., Ramadhan, I., Aisyah, N., Fatmawaty, & Wibawa, T. (2024). Development of dynamic problem solving teaching method in high school physics learning. Jurnal Ilmiah Pendidikan Fisika, 8(2),168–173. https://doi.org/10.20527/jipf.v8i2.11137

Hoehn, J. R., Gifford, J. D., & Finkelstein, N. D (2020). Instructor practices and student engagement in collaborative learning environments in physics. *Physical Review Physics Education Research*, *16*(2). 020106 https://doi.org/10.1103/PhysRevPhysEducRes.16.020106

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365-379. https://doi.org/10.3102/0013189X09339057

Lina, E. Y., & Desnita. (2022). Validity and reliability of critical thinking instruments to measure the effectiveness of context based physics e-module on wave materials. *Jurnal Penelitian dan Pengembangan Pendidikan Fisika*, 8(1), 57–64. https://doi.org/10.21009/1.08106

Liu, Y. (2022). Effects of problem based learning on critical thinking: A meta analysis. *Thinking Skills and Creativity*, 45, 101069. https://doi.org/10.1016/j.tsc.2022.101069

Maruf, M. I., & Mawardi. (2023). Upaya peningkatan collaboration skills melalui pembelajaran problem based learning (PBL) di kelas V SDN Tingkir Tengah 02 Salatiga. *Didaktik: Jurnal Ilmiah PGSD*, 9(4), 2490–2498. https://doi.org/10.36989/didaktik.v9i04.1838

Nasution, S. 2015. *Berbagai pendekatan dalam proses belajar dan mengajar*. Bumi Aksara

Nicholus, G., Muwonge, C. M., & Joseph, N. (2023). The role of problem based learning approach in teaching and learning physics: A systematic literature review. *F1000Research*, 12, 951. https://doi.org/10.12688/f1000research.136339.1

Nirwana, Sartika, D., & Arsyad, A. A. (2021). Penerapan problem based learning untuk meningkatkan kemampuan berpikir analisis fisika siswa SMA. Jurnal Pendidikan dan Pembelajaran, 1(2), 67–74. https://doi.org/10.62388/jpdp.v1i2.9

Nurwahidah, N., Taufik, S., Mirawati, B., & Indriati. (2021). Meningkatkan keterampilan kolaborasi siswa menggunakan lembar kerja siswa berbasis saintifik. *Reflection Journal*, 1(2), 70–76.

Pulgar, J., Fahler, V., & Spina, A. (2021). Investigating how university students collaborate to compose physics problems through structured tasks. *Physical Review Physics Education Research*, 17(1), 010120. https://doi.org/10.1103/PhysRevPhysEducRes.17.010120

Puri, P. R. A., & Perdana, R. (2022). Analisis kemampuan pemahaman konsep fisika peserta didik SMA di Bantul pada materi fluida statis dan upaya peningkatannya melalui model pembelajaran Visualization Auditory Kinesthetic. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *1*(2), 53–61. https://doi.org/10.30822/magneton.v1i2.2463

Putri, C. N. D., Sedyati, R. N., & Zulianto, M. (2023). Students' collaboration and communication skills with problem based learning model. *Jurnal Inovasi dan Teknologi Pembelajaran*, 10(3), 225–233. https://doi.org/10.17977/um031v10i32023p225

Schunk, D. H. (2020). *Learning theories: An educational perspective* (8th ed.). Pearson.

Sepúlveda, J., et al. (2021). Development of collaborative competencies through problem based learning. *Education Sciences*, 11(9), 456. https://doi.org/10.3390/educsci11090456

Sugiyono. (2011). Metode penelitian pendidikan pendekatan kuantitatif, kualitatif, dan R&D. Bandung:Alfabeta

Tarigan, W. P. L., Sipahutar, H., & Harahap, F. (2023). The impact of an interactive digital learning module on students' academic performance and memory retention. *Computers and Children*, 2(2), em004. https://doi.org/10.29333/cac/13654

Widoyoko, E. P. (2017). Teknik penyusunan instrumen penilaian. *Yogyakarta: Pustaka Belajar.*

Wu, Y., Lu, X., & Lin, C. (2024). Bridging disciplines: Enhancing integrative thinking via collaborative problem based learning in higher education. Learning and Instruction, 91, 101930. https://doi.org/10.1016/j.learninstruc.2024.101930

Wiyoko, T. (2019). Pengembangan media pembelajaran fisika berbasis interaktif. Deepublish.

Yulianci, S., Nurjumiati, & Asriyadin. (2020). Analisis karakteristik gaya belajar VAK (Visual, Auditori, Kinestetik) siswa pada pembelajaran fisika. *Jurnal Pendidikan MIPA, 10*(1), 40–44. https://doi.org/10.37630/jpm.v10i1.328

Zahra, S. A., & Iryana, A. (2024). The importance of student learnning styles in determining learning strategies. *International Conference on Learning Community*, 1(1), 2554 – 2558

Zhou, T., & Colomer, J. (2024). Cooperative learning promoting cultural diversity and individual accountability: A systematic review. *Education Sciences,* 14(6), 567. *https://doi.org/10.3390/educsci14060567*