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Problem-solving ability of high school students: Preliminary study analysis using rasch modeling

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Abstract: One of the problems in learning physics is the weak ability of students to solve problems. Therefore, this study aims to conduct a preliminary study to recommend appropriate learning models. The type of research used is survey research. As many as 23 students were involved as primary data sources to determine the need for problem-solving skills. Respondents came from class XI of one of the state high schools in Yogyakarta. Problem-solving ability data was collected using 16 survey items formatted in the Google Form. Data analysis was performed using Rasch modeling. The analysis results show that there are limitations in students' problem-solving skills or abilities. Based on the survey results, it is recommended that the Problem base learning or guided inquiry model can be an alternative to optimizing students' problem-solving abilities.
Keywords: problem-solving; rasch modeling; problem-based l

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Introduction

The ability to solve problems is an essential part of learning. The importance of problem-solving for students is the primary basis for learning physics. This is because problem-solving abilities involve several supporting processes, such as reasoning, interpretation, and evaluation (Wartono et al., 2019). Through solving problems, students can develop critical, logical, and creative thinking (Venisari et al., 2017). According to Hamdani et al. (2019), problem-solving is a high-level cognitive ability that allows students to acquire knowledge and skills.

This shows that learning physics requires problem-solving skills (Sumiantari et al., 2019). One of the problems in learning physics is the weak ability of students to solve problems. Such a situation is caused by the teaching process, which still uses traditional methods which are only teacher-centered and do not provide opportunities for students to develop their thinking (Sujanem et al., 2016). In addition, learning in class emphasizes mastery of concepts and ignores students' abilities to solve physics problems (Azizah et al., 2015). In solving physics problems, students often use mathematical equations directly without analysis (Rahmat et al., 2015). The habit of guessing formulas and memorizing sample questions to solve other problems (Rohayah, 2022).

This will cause students to struggle to solve problems because they cannot solve more complex problems and only solve simpler quantitative problems. One of the goals of studying physics is to create humans who can solve complex problems by applying their knowledge and understanding to everyday situations. However, students experience difficulties because the strategies taught in learning are only designed to solve problems that require mathematical calculations (Hijriani & Hatibe, 2021; Nurul, 2022; Veronica et al., 2020).

Several factors influence students' problem-solving difficulties. One is because of a weak understanding of physics principles and law, a need to understand questions, and student motivation (Makrufi et al., 2018). To overcome this, teachers must change learning methods or models to make physics lessons more fun and motivate students to learn more actively (Gagić et al., 2019). In addition, students must often be given more complex and contextual exercises to practice problem-solving skills (Verschaffel et al., 2020). Several studies have been developed by applying various learning models. However, it has yet to fully increase students' ability to solve physics problems. Research conducted Agustina et al. (2020) shows that applying a project-based learning model can improve problem-solving skills. Students still need help connecting several physics concepts and finding solutions.

On the other hand, Alfika and Mayasari (2018) see the effect of the guided inquiry learning model on students' physics problem-solving abilities. Indicators of planning solutions and reviewing problems in the experimental class are lower than those in the control class. The reason is that the students in the experimental class are in a hurry to work on the problems. When students are in a rush, they tend to neglect essential steps in the problem-solving process, such as reading questions carefully and analyzing the information provided. As a result, they may make avoidable mistakes. In addition, rushing can lead to inaccuracies in complex mathematical calculations, leading to inaccurate and imprecise answers.

The fact is that students need more ability to solve physics problems. This data is based on the analysis results (Setianingrum et al., 2016). The results show an average score of 64.73 students with a low level. Where more than 50% of students can answer questions correctly if asked to define, determine constants, and provide solutions. Students can solve problems easily if they use simple concepts without modification. Then below 50% of students can answer questions correctly using equations, define relationships, give examples, explain, calculate, and determine. Students still need help solving complex questions. In addition, the average value of the quantitative type of questions is more excellent (25.58%) compared to the qualitative value (19.27%). This shows that students are more familiar with quantitative than qualitative model questions.

Other data, Alfika & Mayasari (2018) show that students' average problem-solving ability score is in the less category, namely 50.12%. As many as 42.6% are included in the less category for indicators of understanding the problem. As much as 50.6% are included in the poor category on the indicators of making plans, and more than 50% of students are included in the poor category on the indicators of carrying out plans. At least 60% is included in the sufficient category on the re-examining indicator. Understanding the problem is the lowest indicator because students are not trained to understand in depth the problems related to everyday life. At the same time, the indicators for re-examining are in the sufficient category because students are better trained in sequencing the steps that already exist or have been provided in the questions.

Several studies have conducted preliminary studies on problem-solving abilities. Various limited studies report problem-solving abilities in descriptive form. So, it has yet to be able to provide accurate information as a basis for developing appropriate learning models. Needs analysis up to the individual level needs to be done to get accurate information on students' problem-solving abilities. This will have implications for the effectiveness of selecting strategies and learning models for students. An alternative analysis that can be used is the Rasch model.

The Rasch model provides a more accurate measure of student ability (de Bock et al., 2016). The Rasch model can produce more precise estimates of students' abilities by considering the items' difficulty levels (Pan et al., 2007). In classical theory, the estimation of students' abilities may be inaccurate because they need to adequately consider the difficulty level of the items (Barbera, 2013). The Rasch model allows for a more in-depth analysis of item characteristics, such as difficulty level and item segregation (de Bock et al., 2016). In this study, the Rasch model can identify items that fit well with the measurement model and those that do not (Barbera, 2013; Pan et al., 2007). In classical theory, item analysis is less comprehensive than the Rasch model.

Students' problem-solving abilities can be optimized when using appropriate learning models. The suitability of the learning model can be determined if an empirical needs analysis has been carried out using the Rasch modeling. Therefore, it is necessary to conduct a preliminary study to obtain empirical data on students' problem-solving abilities. This study aimed to conduct a preliminary study of the problem-solving abilities of high school students. This study contributes to providing recommendations for appropriate learning models to be implemented in order to optimize students' physics problem-solving abilities.

Method

This type of survey was conducted at a public senior high school in Yogyakarta, Indonesia. To obtain good data stability, a sample size of 250 is recommended (Chen et al., 2014). However, sample sizes between 16 and 36 can be applied at the 95% confidence level with ±1 logit accuracy for dichotomous data (Linacre, 1994). A total of 23 students were surveyed to get an overview of the needs analysis of students' problem-solving abilities. Respondents consisted of 47.8% women and 52.2% men from class XI MIPA. The classes surveyed were selected based on needs, which are assumed to have diverse abilities. The results of screening using Rasch modeling on student response patterns, as many as one person were excluded from the analysis because they had extreme values.

A preliminary study of students' problem-solving abilities was surveyed using a questionnaire consisting of 16 items. A total of six items were in the form of unfavorable questions (S1, S3, S7, S8, S13 and S14). The answer choices used in the questionnaire were "Yes" and "No" responses. One item (item S1) was excluded from the analysis set because it needed a match with the Rasch modeling (fully explained in the results and discussion section).

All items are formatted using the Google Forms platform to facilitate the administrative process of data collection. Before distributing the questionnaire, the researcher coordinated with the class teacher and asked permission from the school. Before distributing the questionnaire, the researcher explained that the data would be kept confidential and used only for research purposes. Respondents unwilling to participate in the preliminary study are allowed not to fill out the questionnaire because participation is voluntary (Fish, 1999; Sukarelawan et al., 2021). All respondents took 15-20 minutes to answer the questionnaire, which was done outside of study hours.

Preliminary study data of students' problem-solving abilities were analyzed using Rasch modeling. The software used is in the form of Ms. Excel and Winstep 4.6.1 (Linacre, 2021). Ms. Excel is used to prepare raw data to be analyzed using Winsteps. Prior to analysis, all unfavorable items were scored in reverse. The answer "Yes" was given a value of 0, and the answer "No" was 1. Winsteps software was used to analyze data based on Rasch modeling. The Winsteps feature used to analyze the results of the preliminary study of students' problem-solving abilities is a statistical summary to explain the instrument's reliability (Purnami et al., 2021). Item fit is used to analyze the fit to the Rasch modeling (Ramdani et al., 2021). The Wright map is used to analyze the obstacles faced by students related to problem-solving abilities (Hikmah et al., 2021; Sukarelawan & Gustina, 2021). Differential Item Functioning (DIF) is used to analyze the differences in needs between male and female students (Coles et al., 2023; Saghafi et al., 2021).

Results and Discussion

Statistics Summary

The results of the preliminary study instrument reliability analysis are summarized in Table 1.

Table 1. Statistical instrument needs problem-solving abilities

SUMMARY OF 22 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	6.0	15.0	-.53	.69	.96	-.03	.94	.10
SEM	.6	.0	.27	.02	.09	.22	.14	.21
P.SD	2.9	.0	1.22	.09	.40	1.01	.64	.98
S.SD	3.0	.0	1.25	.10	.41	1.03	.65	1.00
MAX.	12.0	15.0	1.84	.92	1.74	1.91	2.35	2.12
MIN.	2.0	15.0	-2.57	.59	.32	-1.37	.14	-1.04

REAL RMSE .74 TRUE SD .97 SEPARATION 1.31 Person RELIABILITY .63
MODEL RMSE .70 TRUE SD 1.00 SEPARATION 1.44 Person RELIABILITY .68
S.E. OF Person MEAN = .27

DELETED: 1 Person
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .72 SEM = 1.55

SUMMARY OF 15 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	8.8	22.0	.00	.57	1.02	.01	.94	-.09
SEM	1.3	.0	.38	.02	.07	.22	.09	.18
P.SD	5.0	.0	1.42	.08	.26	.84	.34	.66
S.SD	5.2	.0	1.47	.08	.27	.87	.35	.68
MAX.	20.0	22.0	1.82	.77	1.52	1.50	1.56	1.02
MIN.	3.0	22.0	-3.32	.49	.48	-1.89	.33	-1.40

REAL RMSE .61 TRUE SD 1.29 SEPARATION 2.10 Item RELIABILITY .82
MODEL RMSE .58 TRUE SD 1.30 SEPARATION 2.26 Item RELIABILITY .84
S.E. OF Item MEAN = .38

Based on Table 1, the instrument has a reliability value of 0.72. This value can be seen in the Cronbach Alpha row (Table 1). This shows a good interaction between the person and the item as a whole (Sumintono & Widhiarso, 2015). At the same time, the person and item reliability values were 0.63 and 0.82, respectively. The reliability value of the person shows the category is quite good, and the reliability of the item shows the category is very good (Sumintono & Widhiarso, 2015). This means that the person consistently answers the instrument, and the items used are in a good category. In addition, Table 1 shows that the average logit item is 0.00, and the average logit person is -0.53. This shows that the person's ability is lower than the difficulty level of the items used. Therefore, a need must be met based on the results of the preliminary study analysis. In Table 1, separation data is also obtained, which is used to determine the distribution of person and item groups (Seamon et al., 2019). The separation value for persons is 1.31 (equivalent to 2 strata), and the separation value for items is 2.10 (equivalent to 3 strata). These two things show that person's needs can be grouped into two levels, and the level of needs can be grouped into three groups. A good separation or strata value for persons is at least 2 (Linacre, 2017), and for items, at least 3 (D. Adams et al., 2020).

Item Fit

The suitability of the items used to analyze the results of the preliminary study is shown in Table 2.

Table 2. Item fit to Rasch modeling

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
1		DELETED											S1
2	11	22	-.56	.49	1.04	.27	.93	-.12	.47	.48	68.2	70.3	S2
3	8	22	.17	.51	.94	-.18	.82	-.41	.55	.49	81.8	74.9	S3
4	9	22	-.08	.50	.83	-.73	.83	-.45	.60	.49	81.8	73.1	S4
5	4	22	1.40	.62	1.00	.13	.69	-.25	.47	.43	81.8	82.8	S5
6	5	22	1.04	.58	.66	-1.10	.44	-1.05	.71	.46	86.4	81.4	S6
7	11	22	-.56	.49	.94	-.24	1.00	.11	.51	.48	77.3	70.3	S7
8	3	22	1.82	.68	1.31	.82	1.49	.77	**.15**	.39	81.8	86.3	S8
9	7	22	.44	.53	1.00	.09	.92	-.07	.50	.49	77.3	77.1	S9
10	19	22	-2.81	.66	1.35	.90	1.36	.65	**.05**	.31	86.4	86.1	S10
11	6	22	.72	.55	1.26	.91	1.13	.42	**.32**	.48	72.7	79.5	S11
12	13	22	-1.04	.49	.92	-.37	.81	-.47	.53	.46	68.2	70.4	S12
13	5	22	1.04	.58	1.52	1.50	1.56	1.02	**.11**	.46	68.2	81.4	S13
14	20	22	-3.32	.77	1.12	.40	1.15	.52	**.15**	.26	90.9	90.7	S14
15	6	22	.72	.55	.88	-.34	.68	-.60	.58	.48	81.8	79.5	S15
16	5	22	1.04	.58	.48	-1.89	.33	-1.40	.80	.46	95.5	81.4	S16
MEAN	8.8	22.0	.00	.57	1.02	.0	.94	-.1			80.0	79.0	
P.SD	5.0	.0	1.42	.08	.26	.8	.34	.7			7.9	6.1	

Based on Table 2, the Outfit Means-Square (MnSq) values range from 0.33 to 1.56, and the Outfit Z-Standard (ZSTD) values range from -1.40 to 1.02. In addition, the Point Measure Correlation (Pt. Mea. Corr.) value ranges from 0.05 to 0.80. Boone et al. (2014a) explained that Outfit MnSq, ZSTD, and Pt. Mea. Corr. can be used as a criterion for evaluating the suitability of test items. If a test item does not meet predetermined criteria, then the item must be corrected, replaced, or removed from the analysis. The guide Boone et al. (2014b) proposed to assess item suitability criteria: Outfit MnSq between 0.5 - 1.5, Outfit ZSTD -2.0 to +2.0, and PT. Mea. Corr. between 0.40 - 0.85.

This study found that of the 16 test items tested using the Rasch modeling, as many as 15 items were declared fit (valid) and could be used to analyze the needs of students' problem-solving abilities. A total of 8 items (S2, S3, S4, S5, S7, S9, S12, and S15) showed a good fit with the Rasch model, while seven items (S6, S8, S10, S11, S13, S14, and S16) showed a poor fit. Even so, the seven items can still be maintained because they meet the predetermined criteria' tolerance limits. Items S6 and S16 are retained because of the outfit ZSTD and Pt. Mea. Corr. values still meet the criteria, even though the outfit MnSq value is out of range. Items S8, S10, S11, S13, and S14 are retained because the Outfit MnSq and Outfit ZSTD values meet the criteria even though the Pt. Mea. Corr. outside the acceptance range but still positive. S1 items were excluded from the analysis because all three criteria were outside the acceptance threshold.

Wright Map

Mapping the needs of the preliminary study results is visualized using a Wright map, as shown in Figure 1. Figure 1 shows the mapping of the preliminary study results of students' problem-solving abilities. Based on Figure 1, students' needs regarding problem-solving skills are grouped into four levels, namely Very Needed (2 items, S5 and S8), Needed (7 items, S3, S6, S9, S11, S13, S15, and S16), Simply Needed (4 items, S2, S4, S7, and S12), and Less Needed (S10 and S14). This division of the four levels refers to the Logit Value of Item (LVI) (Ramdhan et al., 2022). The LVI value is determined using the average value and standard deviation of the logit value of each item.

Referring to the Wright map, about 82% (18 out of 22 people) of students have more than a 50% chance of very needing items S5 and S8. According to the results of a preliminary study of problem-solving abilities in the Needed group, about 73% (16 out of 22 people) of students have more than a 50% chance of needing S3, S6, S9, S11, S13, S15, and S16 items. In the third group, approximately 36.4% (8 out of 22) of students had more than a 50% chance of simply needing S2, S4, S7, and S12 items. In the less needy group, no students have more than a 50% chance of being included because all students have a higher logit value than the items in that group. So, the preliminary study results empirically show that problems S10, "I want the material that I have learned to be applied to a project or work," and S14, "I am not interested in learning physics through direct experiments." is not a problem students face.

The results of the mapping show that item S5 "Physics is an easy subject for me," has the highest logit value of the 15 items, so it is in the very needed group. So far, students still feel that physics is a difficult subject. Often, physics is seen as difficult because it involves abstract concepts (Alias et al., 2013), so it is complicated to be understood visually by most students. In addition, physics also involves solving complex problems (W. K. Adams & Wieman, 2015), requiring critical thinking (Dinsmore & Fryer, 2023; McBride, 2023) and good mathematical skills (Bing & Redish, 2009). On the other hand, the teacher's monotonous teaching method reduces students' interest and motivation in studying physics, giving the impression of physics as tedious and difficult material. This is in line with the view of Ornek et al. (2008), who said that students' views of the lesson influence their understanding and learning. However, the results of an empirical preliminary study show that teachers teach using various methods (see S8). In contrast, items S10 "I want the material that I have learned to be applied to a project/work." and S14, "I'm not interested in learning physics through direct experiments." are in the Less Needed group.

Differential Item Functioning by gender

The results of the analysis of differences in the needs of the preliminary study of problem-solving skills based on gender are shown in Figure 2. Statistically, Figure 2 shows that 1 out of 15 items responded differently by gender. S5 item, “Physics is an easy subject for me,” was responded to differently by male and female students. Statements in item S5 are needed more by female than male students. Even so, no research results provide clear answers as to why physics lessons are easier for boys than girls. However, few studies have investigated gender differences in physics learning and achievement. Kalender et al. (2020) found that women report lower self-efficacy than men in physics, which may affect their engagement, participation, and retention in academic careers in STEM. Other studies have also investigated gender differences in physics learning and achievement, but the results are varied and complex (Kalender et al., 2019; Maries et al., 2018; Nurdian Susilowati et al., 2020; Steegh et al., 2019). Performance differences between male and female students can be reduced or even eliminated by using interactive engagement techniques in introductory physics classes (Pollock et al., 2007).

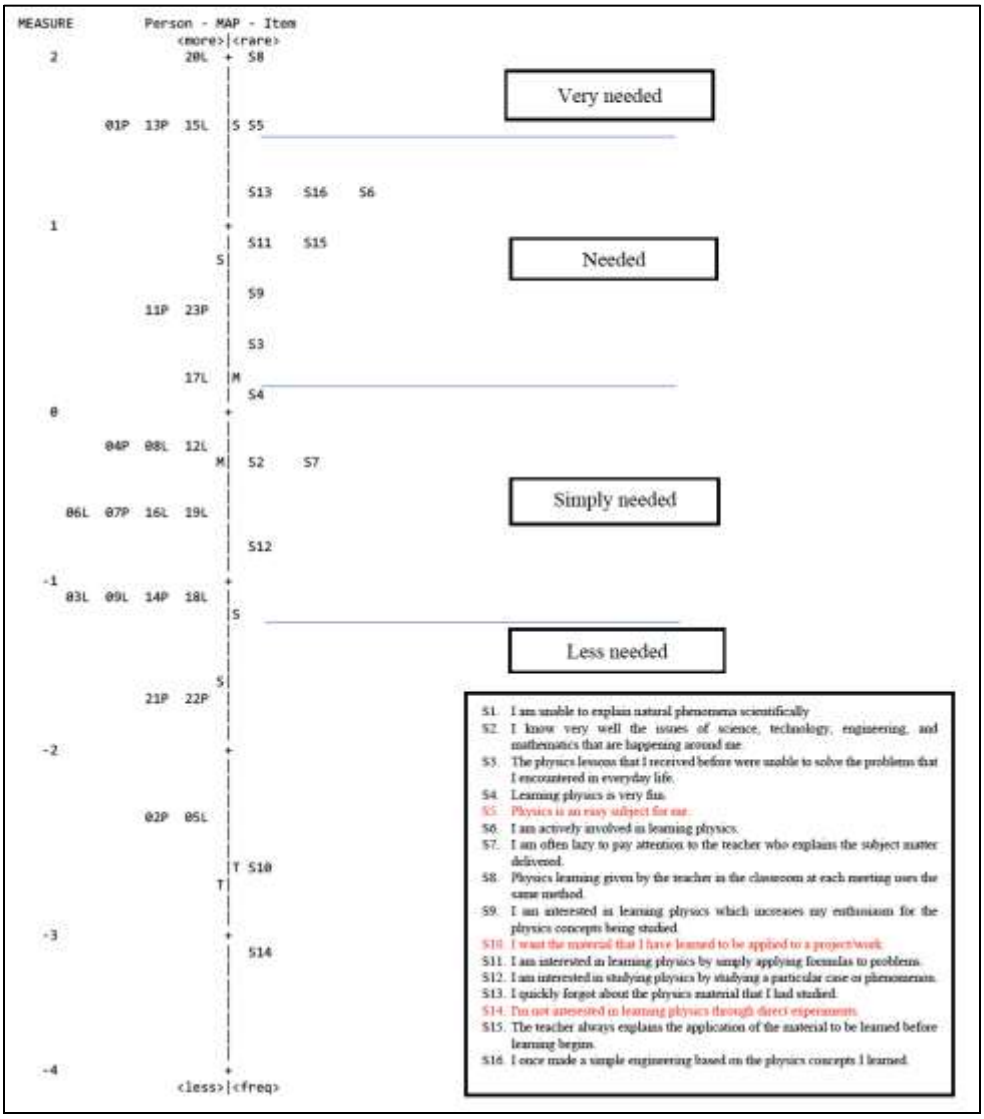

Figure 1. Wright map analysis preliminary study of students' problem-solving abilities

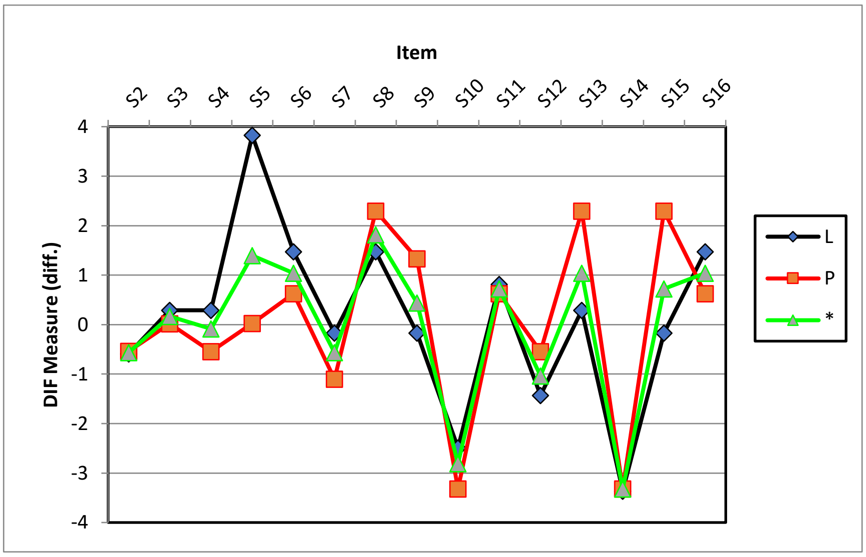

Figure 2. Preliminary study analysis of students' problem-solving abilities based on gender

Learning model recommendations

Based on the findings presented earlier, problem-solving-oriented learning can be considered by teachers as an effective approach. Problem-solving-oriented learning allows students to think actively, collaborate with classmates, and solve problems independently. In addition, context-based learning and student engagement can train them to see the relevance of learning materials to the real world and their daily lives. Presenting contexts related to students' lives can motivate and increase their enthusiasm for learning physics. Active and collaborative learning can encourage students to participate more actively in the learning process and collaborate with classmates. Active learning models such as problem-based learning, cooperative learning, or project-based learning can be an appropriate choice to realize student-centered learning (Huang, 2023; Mendo-Lázaro et al., 2022; Mudrikah, 2021). Through this approach, students not only gain theoretical understanding but also practical skills relevant to their lives, thus improving the overall quality of education.

Problem-based learning (PBL) is a pedagogical approach that can engage students in solving real problems through group collaboration and discussion, as stated by Mustaghfirin (2022). This PBL model serves as a means to assist students in developing problem-solving skills by providing an accurate and relevant context so that students can apply their knowledge in real situations (Mustaghfirin, 2022).

In addition to PBL, the guided inquiry learning model is also recommended as an effective alternative. According to research conducted by Cahaya et al. (2023), the guided inquiry model can not only be used to analyze the needs of students' problem-solving abilities, but it can also involve them actively in the learning process. This model encourages students to develop various important skills such as critical thinking, creativity, and speaking ability (Febiyanti et al., 2020; Suwardi, 2021).

Guided inquiry learning puts students at the center of the learning process, encouraging them to ask questions, explore, and find their answers, which in turn can increase their engagement and motivation in learning. Thus, the integration of PBL and guided inquiry learning in the education curriculum can result in more comprehensive and meaningful learning for students, which focuses not only on theoretical aspects but also on developing practical skills relevant to their daily lives.

Conclusion

Based on the results of the preliminary studies that have been conducted, there are limitations in students' problem-solving skills or abilities. Problem-solving-oriented learning, context-based and engagement learning, and active and collaborative learning can be a consideration for teachers. Optimization of problem-solving abilities can be done by implementing Problem-based learning or guided inquiry learning models. This study has several limitations that need to be considered. Firstly, the sample size used in this study is relatively small, which is only 23 students. This has an impact on the accuracy and confidence level of the description of students' problem-solving skills in general. In addition, this study was only conducted in one high school in Yogyakarta, Indonesia, so the results cannot be generalized to a wider context or other schools with different characteristics. Future research should consider several aspects to overcome the limitations mentioned. First, increasing the sample size and involving more schools from different regions will increase the representativeness and generalisability of the results.

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