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Exploring Scientific Inquiry Literacy Among Physics Teachers

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Abstract: This study aims to examine the Scientific Inquiry Literacy (SIL) of in-service physics teachers in West Java. focusing on three key aspects: knowledge. skills. and attitudes toward scientific inquiry. The research addresses the need to understand teachers' readiness to implement inquiry-based instruction as part of quality science education. A descriptive survey design was employed involving 27 physics teachers from various cities and regencies in West Java. Participants were selected through purposive sampling based on their active teaching status and academic background. Data were collected via an online questionnaire using the Scientific Inquiry Literacy Instrument (SILI). which comprises 35 multiple-choice items on knowledge. 39 on skills. and 30 attitude statements. Rasch Model analysis was applied to evaluate person and item measures. reliability. and item difficulty. with Wright Map outputs used to visualize the distribution of teacher abilities. Results showed that the overall SIL of participating teachers was relatively high. as indicated by a mean person measure above the item mean across all aspects. Among the three aspects. the attitude aspect (AA) yielded the highest person measure (1.57). followed by knowledge (KA) at 0.50 and skills (SA) at 0.13. Despite these strengths. the data revealed a mismatch between teacher ability and item difficulty in some areas. suggesting a potential ceiling effect and room for improvement. particularly in applying complex inquiry skills. While physics teachers in this study demonstrate a generally strong level of scientific inquiry literacy. the use of non-probability sampling and a small sample size limits the generalizability of the findings. Targeted professional development is recommended to strengthen teachers' competencies in complex inquiry practices and to support the continued integration of inquiry-based learning in physics classrooms.

Keywords: scientific inquiry literacy. inquiry-based learning. physics teachers.

▪ INTRODUCTION

In the context of the 21st century. the development of competencies such as critical thinking. problem-solving. communication. and collaboration is indispensable for navigating the complexities of a technology-driven society. These competencies are closely connected to scientific literacy. which encompasses the ability to construct scientific understanding. critically evaluate evidence. and apply reasoning to real-world phenomena. Inquiry-based science education fosters these skills by engaging learners in authentic. reflective. and technology-supported learning experiences (Morris. 2025; Alarcon et al.. 2023). Scientific literacy not only serves academic goals but also equips individuals to engage meaningfully in civic and societal decisions informed by science (Duncan et al.. 2021; Ma. 2023). In primary science education. inquiry-based instruction has also demonstrated effectiveness in enhancing students' learning-to-learn competence. which is considered one of the core components of lifelong learning in the 21st century (Letina. 2020).

Scientific inquiry plays a pivotal role in cultivating these competencies by engaging learners in authentic investigations. metacognitive reflection. and epistemic agency (Duncan et al.. 2021; Ješková et al.. 2022; Pozuelo-Muñoz et al.. 2023). Inquiry-based learning promotes deeper reasoning and helps learners construct scientific knowledge

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through cycles of questioning. data collection. analysis. and explanation (Urdanivia Alarcon et al.. 2023). Moreover. open and technology-integrated inquiry models have been found effective in enhancing conceptual understanding. motivation. and 21st-century skills. especially in physics classrooms (Abaniel. 2021; Kamarudin et al.. 2024; Novitra et al.. 2021).

In addition. inquiry-based science education has also been shown to significantly improve students' oral and written communication skills when implemented through authentic and problem-based activities (Vilela et al.. 2025). This is further supported by evidence that inquiry-based instruction increases motivation among both low and non-low achievers in science. although it may also be associated with increased exam anxiety. especially among students with weaker math skills (Kuo et al.. 2019). For example. empirical studies in middle school contexts reveal that inquiry-based instruction can help up to 82% of students exceed expected learning gains in both science concepts and scientific practices (Marshall et al.. 2017). However. it is worth noting that inquiry-based instruction. while positively associated with interest. enjoyment. and scientific self-efficacy. may not always correlate strongly with science achievement. particularly in cross-national contexts. This observation highlights the importance of instructional quality and adaptation to local needs (Cairns & Areepattamannil. 2019).

These diverse and far-reaching benefits underscore the transformative potential of scientific inquiry. which has led to its widespread adoption as a central component in contemporary science education reforms. When integrated with instructional models such as STEM. project-based. or problem-based learning. inquiry-based approaches further enhance the development of students' critical thinking. creativity. and scientific reasoning (AlAli. 2024; Hebebci & Usta. 2022; Topsakal et al.. 2022). These competencies are crucial not only for academic success but also for addressing real-world problems in a technology-driven society. By engaging in scientific practices such as questioning. experimenting. interpreting evidence. and constructing explanations. students build stronger scientific literacy and are better equipped to navigate complex scientific and societal challenges (Chen & Chen. 2021; Lu et al.. 2020; Tan et al.. 2023).

Given the central role of inquiry in fostering scientific literacy. physics teachers play a pivotal role in designing meaningful inquiry-based learning experiences. A solid understanding of scientific inquiry is essential. as recent studies show that inquiry-based instruction more effectively supports students' conceptual understanding than direct instruction. while combining both approaches yields optimal results (de Jong et al.. 2023). Moreover. integrating practical inquiry within STEM problem-solving has been shown to bridge the gap between abstract scientific concepts and real-world applications. enhancing the relevance and quality of student learning (Tan et al.. 2023). Furthermore. a recent study emphasizes that students' high motivation in inquiry activities does not always align with high performance. indicating the crucial role of teacher support and instructional design to bridge this gap (Ham et al.. 2025). This underscores the essential role of physics teachers in effectively implementing inquiry-based learning to foster student competencies.

The focus on physics teachers in particular is well justified. given that physics as a scientific discipline is inherently inquiry-driven. relying heavily on experimentation. observation. and modeling to build conceptual understanding (Meulenbroeks et al.. 2024; Shi et al.. 2025; Thacker. 2023; Worachak et al.. 2023). To convey this nature effectively.

teachers must be well-versed in scientific inquiry practices. With appropriate scaffolding. inquiry-based learning in physics has been shown to significantly enhance students' critical thinking. motivation. and conceptual understanding (Meulenbroeks et al.. 2024; Novitra et al.. 2021; Worachak et al.. 2023). Therefore. strengthening physics teachers' scientific inquiry literacy is crucial to improving physics education quality and equipping students with competencies essential for the 21st century (Novitra et al.. 2021;Ibrahim & Mahmud. 2020).

To fully understand the role of scientific inquiry in science education. recent studies highlight the importance of developing specific scientific reasoning skills that enable students to meaningfully construct. evaluate. and apply scientific knowledge through inquiry activities (Stender et al.. 2018). A balanced pedagogical approach that combines inquiry-based learning with direct instruction is more effective in fostering both deep reasoning and foundational understanding than either method alone (de Jong et al.. 2023). Moreover. inquiry-based online learning. particularly when integrated with virtual laboratories. enhances students' scientific argumentation skills. especially in constructing evidence-based claims (Hendratmoko et al.. 2023). While inquiry promotes long-term retention of reasoning skills. direct instruction supports immediate acquisition. highlighting the need for carefully designed instructional strategies to optimize outcomes (Kaiser et al.. 2018).

The nature of scientific inquiry (NOSI) is regarded as a critical component of scientific literacy in current science education reforms Mesci et al. (2020). However. recent research highlights that many pre-service science teachers still hold fragmented or partial understandings of NOSI. suggesting the need for improved pedagogical training in teacher education programs (Khaokhajorn & Srisawasdi. 2024). According to Bevins & Price (2016) and Morris (2025). inquiry-based approaches are designed to reflect the authentic practices of scientists. encouraging students to engage with the conceptual. procedural. and personal dimensions of scientific activity. This authentic engagement fosters deeper understanding and increases students' willingness to participate in science throughout their education.

Furthermore. Ekici & Erdem (2020) and Alarcon et al. (2023) emphasize that inquiry-based activities are among the most effective methods for cultivating critical thinking. scientific reasoning. and process skills. which are essential components of scientific literacy in today's society. To ensure broad accessibility and instructional effectiveness. Uum et al. (2016) and Morris (2025) argue that modern inquiry frameworks should balance hands-on investigation with scaffolded reasoning and explanation. Such an approach enhances the adaptability of inquiry-based instruction and supports diverse student learning needs across various classroom contexts.

Recent studies have highlighted persistent challenges in scientific literacy across Indonesia. Students' proficiency in scientific inquiry remains low to moderate across science topics and educational levels. from junior to senior high school (Ramli et al.. 2022; Indasa & Jauhariyah. 2024). These challenges include limited conceptual understanding. difficulty in applying inquiry skills. and low motivation or engagement in science learning. Similar concerns have been reported internationally. where inquiry-based instruction can improve students' attitudes toward science but does not always translate into high academic achievement. particularly in complex content areas. These findings underscore the importance of instructional quality and contextual adaptation (Cairns & Areepattamannil. 2019).

These findings. observed across various science topics and educational levels. reflect not isolated issues but broader systemic challenges in Indonesia's science education. Scientific literacy among students consistently falls within the low to medium range. revealing not only variable learning outcomes but also deeper concerns related to instructional practices. curriculum implementation. and support for science learning (Faisal & Martin. 2019; Nugroho et al.. 2019). These systemic patterns indicate that scientific literacy challenges are not merely student-centered but are embedded across the educational ecosystem. including teacher preparation and professional development.

The challenge of scientific literacy is not limited to students. Studies have also revealed low levels of scientific literacy among both pre-service and in-service teachers. Many teacher candidates struggle to apply inquiry methods. analyze scientific information. and construct evidence-based explanations (Miarsyah et al.. 2020; Sari & Nurdin. 2025). These findings point to the need for improved teacher education programs. instructional modules. and support systems to better prepare educators for implementing inquiry-based science education. Similar challenges have been reported internationally. where difficulties in applying inquiry-based instruction are often linked to fragmented understandings of inquiry and limited opportunities for authentic practice during school placements (Khaokhajorn & Srisawasdi. 2024; Strat et al.. 2024).

Developing scientific inquiry literacy among teachers is essential not only for professional competence but also for improving student learning outcomes. The continuity between students. pre-service teachers. and in-service teachers suggests that student-level challenges may partly stem from the inquiry competencies and instructional approaches of current educators. In-service teachers play a critical role in modeling and facilitating inquiry-based learning; their ability to guide these processes directly influences both classroom practice and teacher preparation. However. implementing inquiry-based practical work in secondary science education is often hindered by difficulties in initiation. planning. execution. and evaluation. Many of these challenges arise from inadequate teacher competencies and pedagogical orientations (Akuma & Callaghan. 2019).

Given these persistent challenges. there is a critical need to evaluate the current state of scientific inquiry literacy among in-service teachers. To address this gap. the present study aims to assess the scientific inquiry literacy of physics teachers in West Java. This study focuses on scientific inquiry literacy in relation to an individual's understanding of the fundamental nature of science. with particular emphasis on the discipline of physics. The primary objective is to map the current state of scientific inquiry literacy among in-service physics teachers by employing the Scientific Inquiry Literacy Instrument (SILI). developed by Darman et al. (2024). The SILI framework encompasses three key dimensions: knowledge. skills. and attitude.

▪ METHOD

Participants

This study involved 27 in-service physics teachers from various public and private secondary schools across several districts in West Java. Indonesia. The participants were selected using a purposive sampling technique. targeting teachers who (1) actively teaching physics at the secondary school level (SMA/MA in West Java. (2) hold at least a bachelor's degree in physics or physics education. (3) having at least two years of teaching experience. and (4) consented to participate in the study voluntarily. The purposive sampling was chosen to ensure that the participants possessed relevant academic backgrounds and practical teaching experience aligned with the objectives of the study. Table 1 presents the demographic information of the participants.

Table 1. Demographic Information of Participants

City in West Java	Frequently	Percentage (%)
Tasikmalaya	4	14.81
Tasikmalaya Regency	3	11.11
Garut	1	3.70
Garut Regency	2	7.40
Indramayu	1	3.70
Bandung Regency	1	3.70
Sukabumi Regency	1	3.70
Bekasi	5	18.51
Bandung City	5	18.51
Purwakarta	1	3.70
Ciamis Regency	1	3.70
Banjar	1	3.70
Kuningan Regency	1	3.70
Total	**27**	

It is important to note that the use of a non-probability sampling method and a relatively small sample size may limit the generalizability of the findings. The results of this study should therefore be interpreted with caution. as they reflect the characteristics and inquiry literacy of a specific group of teachers rather than the entire population of physics educators in West Java.

Research Design and Procedures

A descriptive survey design was employed to investigate the scientific inquiry literacy of physics teachers. This approach was selected to allow a systematic description and profiling of the participants' competencies in scientific inquiry. based on their responses to a standardized instrument. The design is consistent with the descriptive aims outlined by Dubin. Malhotra. and Wacker (in Zheng et al.. 2019) which emphasizes exploring and identifying the presence and distribution of specific attributes within a population.

The research was conducted over a period of two weeks in May 2024. during which data were collected through an online questionnaire using Google Forms. Participants were invited to complete the instrument independently. and they were assured of confidentiality and voluntary participation. While the online distribution allowed for broader geographic reach. the potential limitation of uncontrolled testing environments was acknowledged. as participants may have consulted external sources when answering the questions.

Instruments

This study utilized the Scientific Inquiry Literacy Instrument (SILI). developed and validated by (Darman et al.. 2024) to assess the scientific inquiry literacy of in-service physics teachers. The SILI instrument was specifically designed for science educators and comprises three core dimensions: knowledge. skills. and attitudes toward scientific inquiry. The knowledge component consists of 35 multiple-choice questions (five answer options per item) and is structured around 28 indicators reflecting teachers' understanding of key inquiry concepts (see Table 2).

Table 2. SILI indicators for knowledge aspects

Aspect	SILI Indicators for Knowledge Aspect	SILI's Items
Knowledge of definitions. understandings. terms. types. and inquiry positions	Knowledge of the meaning of inquiry	1
	Know the wisdom that underlies the inquiry approach	6
	Know other terms for inquiry	2.4
	Know the types of inquiry in learning	33
	Know the position of inquiry in learning	34
Knowledge of concepts related to inquiry	Knowledge of the concept of observation in inquiry	3
	Distinguish between practice. observation. experiment. measurement. and practicum	9
	Know the experimental activities of inquiry well	8
	Be well acquainted with the concept of generalization	19
	Get to know the concept of the scientific method well	20
	Get to know the parts of the scientific method well	35
	Familiar with the concept and orientation of inquiry experimental activities	21.32
	Get to know the concept of classification well	22.26
Knowledge of supporting skills for inquiry activities	Good knowledge of science process skills	27.29
	Know observation skills	23
	Know classification skills	22
	Know about measurement skills	25
	Know about communication skills	18.24
	Get to know about generalization (concluding) skills	30
	Be well acquainted with the concept of predictive ability	28
Knowledge of the steps for inquiry activities	Knowledge of the concept of hypothesis	5
	Know the form of a guide for scientific inquiry activities	7

Aspect	SILI Indicators for Knowledge Aspect	SILI's Items
	Get to know the tools and materials for science experimental activities	10.11
	Get to know the types of variables in science practical activities	12.13
	Know the presentation of data from the inquiry practicum result	16
	Know the differences between graphs and diagrams as a result of inquiry activities	17

Based on (Darman et al.. 2024) The skills component includes 39 multiple-choice questions (four answer options per item). aligned with the stages of scientific inquiry and mapped onto the corresponding skill indicators (see Table 3).

Table 3. SILI indicators of skill aspects

No	Stages of Scientific Inquiry	Indicators of SILI Questions for Skills Aspects	SILI'S Items
1.	Identify the problem that will be investigated	1. Identify that the problem will be investigated for the given phenomenon	29
2.	Use of deduction. formulation of hypotheses. or combining logical models and proofs	2.1 Formulate the best hypothesis from a scientific problem	12.38
		2.2 Formulate and revise scientific explanations and models with the use of logic and evidence	20
		2.3 Give scientific proof to support the claim	22
		2.4 Provide an evaluation of the given hypothesis	24
		2.5 Provide an explanation hypothesis based on the condition's beginning and end phenomenon	30
3.	Use deduction to produce predictions from hypotheses or models	3. Use deduction from a law to make a prediction	37
4.	Design an experimental procedure to test predictions	4. Sequence the experimental science process presented in a random way	1
		Table Title	
5.	Conduct a scientific experiment. observation. or simulation to test a hypothesis or a model: 1. Identify the test system. 2. Identify and define variables operationally; 3. Perform the experiment	5.1 Refine the test design with a specific objective	4
		5.2 Design a test with a specific objective	9
		5.3 Determine the best way to collect data for a scientific investigation	33.34
		5.4 Explain the error inside a test	5

No	Stages of Scientific Inquiry	Indicators of SILI Questions for Skills Aspects	SILI'S Items
		5.5 Select and explain the suitable material for the test based on the list of ingredients in the table	25
		5.6 Explain error variables in the test	3
		5.7 Determine and provide an accurate reason for taking samples in data collection in an experiment	26
6.	Collect. organize. and analyze data thoroughly. accurately. and precisely: 1. Analyze data for trends and relationships; 2. Create and interpret a chart; 3. Use induction and develop a law based on evidence and a graph	6.1 Interpret data-based study results	14
		6.2 Determine valid data based on the picture distribution of the data presented	27
		6.3 Determine a valid way of data collection based on the situation	28
		6.4 Explain the data deviation in a test result chart	15
		6.5 Make an interesting conclusion based on the data in the test result graph	16
		6.6 Determine the most appropriate variable based on the data in the graph	18
		6.7 Give the meaning of the trend based on the data presented in the form of a data table	23
		6.8 Explain the meaning of the data given in a graph that intersects at an axis	19
		6.9 Make an interesting conclusion based on the data in the table provided	36
		6.10 Provide an opinion to state something based on the data in the graph	6
		6.11 Interpret the given graph based on the results of the data observation	10
		6.12 Make an interesting conclusion based on the analysis of the data in the graphs presented	17
		6.13 Create a chart based on the given data	39
		6.14 Create a decision based on experimental data	13
7.	Apply numerical and statistical methods to obtain and support a conclusion: 1. Use technology and mathematics	7.1 Provide the correct reason for data processing a test to obtain a conclusion	32
		7.2 Give an opinion for correct conclusions drawn from an	2

No	Stages of Scientific Inquiry	Indicators of SILI Questions for Skills Aspects	SILI'S Items
	2. Make an interesting. correct conclusion from the proof	experiment (an interesting conclusion from evidence)	
		7.3 Make an interesting conclusion based on the graph of the given data	11
		7.4 Make an interesting conclusion comparing quantitative/qualitative ways or subjective/objective data	31
		7.5 Declare agreement or no agreement. along with the reason for the conclusions presented based on the proof	35
8.	Explain the unexpected result: **1.** Formulate a hypothesis or alternative models. **2.** Identify and communicate sources; errors cannot be avoided **3.** Identify the reason for the inconsistent result	8.1 Recognize and analyze alternative explanations and models	21
		8.2 Give a reason for the data that was obtained that was not reasonable in a graph (experiment error)	8
		8.3 Give a reason for a found trend or relationship that is not fair in the graph	7

The attitude component comprised 30 items representing key indicators aligned with the role of inquiry in physics teaching. including cognitive. affective. and social dimensions. Each item was phrased as either a positive or negative statement. and responses were scored using a four-point Likert scale. with reverse scoring applied to negative statements. following the structure established by Darman et al. (2024).

To interpret the distribution of teacher abilities in each aspect of scientific inquiry literacy. person logit values from the Rasch analysis were classified into high. moderate. and low levels using the mean and standard deviation (SD) of person measures (see Table 8). Using the mean ± SD approach as a threshold. the logit scores were segmented accordingly. The resulting cut-off values and corresponding categories are presented in Table 4 for the knowledge aspect. Table 5 for the skills aspect. and Table 6 for the attitude aspect.

Table 4. Logit categories for knowledge aspect

Logit Value	Category
≥ 1.09	High
$-0.09 < x < 1.09$	Moderate
≤ -0.09	Low

Table 5. Logit categories for skills aspect

Logit Value	Category
≥ 0.80	High
$-0.54 < x < 0.80$	Moderate
≤ -0.54	Low

Table 6. Logit categories for attitude aspect

Logit Value	Category
≥ 3.36	High
0.24 < x < 3.35	Moderate
≤ 0.24	Low

To ensure psychometric robustness. Darman et al. (2024) validated the instrument using the Rasch measurement model. Construct validity was established through analyses of Outfit Mean Square (MNSQ). Z-Standard (ZSTD). and Point Measure Correlation (Pt Mean Corr). all of which were within acceptable ranges. In terms of reliability. the item reliability scores were 0.98 (knowledge) and 0.96 (skills). while person reliability values were 0.73 and 0.74. respectively. The Cronbach's Alpha coefficients were 0.72 for the knowledge domain and 0.76 for the skills domain. Unidimensionality was also confirmed. with explained variances exceeding the recommended 20% threshold (26.9% for knowledge and 20.4% for skills).

Data Analysis

The quantitative data obtained from the SILI results were analyzed using the Rasch Model. with Winsteps version 3.73 software. The output from the Wright Map in the Rasch Model illustrates the Scientific Inquiry Literacy (SIL) profile of physics teachers on the left side. and the difficulty levels of the questions on the right side. Only the relevant portion of the Wright Map that is essential for the explanation and analysis is presented (Boone & Staver. 2020). The Wright Map includes symbols such as "T" for teacher. "M" for male. "W" for female. and "Q" for question items. The "M" symbol represents the average. "S" marks the standard deviation at both the top and bottom of the average. while "T" indicates two standard deviations at the upper and lower ends of the distribution (Boone & Staver. 2020).

Additionally. the Rasch Model was chosen for this study due to its methodological advantages over classical test theory (CTT) in terms of data transformation. precision. and interpretability. Unlike CTT. which treats raw ordinal scores as if they were interval data. the Rasch model transforms ordinal responses into logit units based on the odds of success. enabling more accurate and probabilistic inferences about both item difficulty and respondent ability (Raccanello et al.. 2019; Yu. 2020). This approach preserves the continuous nature of quantitative data and enhances measurement precision. Additionally. Rasch analysis offers a unified framework for mapping item difficulty and participant ability on a single continuum through the Wright Map (Planinic et al.. 2019). while also accounting for missing data patterns more effectively (Kazemi et al.. 2020). These strengths made the Rasch model an appropriate analytical tool for assessing teachers' scientific inquiry literacy with improved reliability and validity compared to traditional methods.

▪ RESULT AND DISSCUSSION

The results of the SIL test for physics teachers were analyzed using Rasch model measurement with the Winsteps application version 3.75. to assess the teachers' abilities across three aspects of SIL: Knowledge Aspects (KA). Skills Aspects (SA). and Attitude Aspects (AA). As presented in Table 6. the person measure SIL values for the knowledge aspect (KA) is 0.50. the skills aspect (SA) is 0.13. and the attitude aspect (AA) is 1.57.

The person measure value for the knowledge aspect exceeds the baseline value of 0.0. indicating that the teachers' abilities are generally greater than the difficulty level of the questions (Sumintono & Widhiarso. 2014).

Table 7. Summary statistics' the three aspect of SIL

No	Aspect of SIL	Person Measure	Reliability		Infit MNSQ		Outfit MNSQ		Separation	
			Person	Item	Person	Item	Person	Item	Person	Item
1	KA	0.50	0.33	0.87	1.00	0.99	1.00	1.00	0.70	2.65
2	SA	0.13	0.64	0.86	1.00	0.99	1.01	1.01	1.34	2.46
3	AA	1.57	0.87	0.85	1.04	1.00	1.00	1.00	2.64	2.39

As shown in Table 7. the person reliability for the Knowledge Aspect (KA) is 0.33. for the Skills Aspect (SA) is 0.64. and for the Attitude Aspect (AA) is 0.87. Meanwhile. item reliability for the KA is 0.87. for the SA is 0.64. and for the AA is 0.85. According to (Sumintono & Widhiarso. 2014) these values indicate that while the consistency of the respondents' answers is relatively low. the quality of the items in the instrument is good. The ideal infit and outfit MNSQ values for persons are close to 0.0. with values approaching 0.0 indicating better quality. Similarly. this applies to the item tables for infit and outfit MNSQ. The interaction between persons and items is visually represented in the Wright Map. which shows a person-item distribution map (Hikmah et al.. 2021). Figures 1. 2. and 3 present the interaction of physics teachers' responses to SIL items for the knowledge. skills. and attitude aspects. respectively.

Table 8 outlines the individuals with the highest total scores in each aspect: for the knowledge aspect. the highest scores were achieved by 05W. 08M. 10W. 12M. 20M. and 27W. each scoring 25 out of 35. In the skills aspect. the highest scores were attained by 06M and 16W. with both achieving 28 out of 30. For the attitude aspect. 04M achieved the highest possible score of 120 out of 120. Conversely. the lowest scores were as follows: in the knowledge aspect. 07M scored 16 out of 35; in the skills aspect. the lowest score was 12 out of 39; and in the attitude aspect. 01M and 09M each scored 79 out of 120.

Table 8. JMLE Measure. outfit MNSQ. outfit MNSQ. outfit ZSTD. and PT Measure-Corr Person

Person	TOTAL SCORE			JMLE MEASURE			Outfit MNSQ			Outfit ZSTD			PT Measure-Corr		
	KA	SA	AA	KA	SA	AA	KA	SA	AA	KA	SA	AA	KA	SA	AA
01M	21	12	79	0.28	-1.12	0.00	1.84	1.44	2.70	2.0	1.1	4.1	0.41	0.20	0.40
02W	24	19	109	0.90	-0.12	3.25	0.79	0.90	1.72	-0.4	-0.3	2.1	0.59	0.53	0.38
03W	21	19	92	0.28	-0.12	1.14	0.91	0.81	0.88	-0.1	-0.7	-0.3	0.63	0.58	0.58
04M	23	24	120	0.69	0.59	7.61	1.24	1.11	max	0.7	0.5	max	0.54	0.44	0.00
05W	25	20	90	1.11	0.02	0.94	0.38	1.41	0.26	-1.5	1.5	-3.7	0.72	0.38	0.48
06M	22	28	100	0.49	1.23	2.02	1.11	1.08	0.86	0.4	0.3	-0.5	0.55	0.43	0.45
07M	16	13	86	-0.71	-0.97	0.57	0.91	0.96	0.32	-0.1	0.0	-3.1	0.67	0.40	0.44
08M	25	25	80	1.11	0.74	0.08	0.44	0.91	0.42	-1.3	-0.2	-2.4	0.69	0.57	0.56
09M	14	13	79	-1.12	-0.97	0.00	1.20	0.96	0.42	0.5	0.0	-2.5	0.59	0.41	0.71
10W	25	26	105	1.11	0.90	2.66	0.38	0.63	0.58	-1.5	-1.2	-1.9	0.72	0.69	0.79
11W	17	12	83	-0.51	-1.12	0.32	1.39	2.36	0.61	1.39	2.6	-1.4	0.50	0.19	0.42
12M	25	22	103	1.11	0.30	2.40	0.98	1.20	1.31	0.1	0.8	1.3	0.50	0.39	-0.1
13M	20	20	86	0.09	0.02	0.57	1.44	0.89	0.23	1.2	-0.4	-3.9	0.55	0.60	0.59
14W	23	23	107	0.69	0.44	2.95	0.40	0.93	0.98	-1.8	-0.2	0.0	0.75	0.54	0.73
15W	22	24	110	0.49	0.59	3.42	0.43	0.86	0.62	-1.8	-0.4	-1.3	0.76	0.57	0.63
16W	23	28	100	0.69	1.23	2.02	1.25	0.74	1.12	0.7	-0.6	0.6	0.52	0.59	0.37
17W	17	21	91	-0.51	0.16	1.04	2.12	1.77	2.07	2.4	2.5	3.0	0.55	0.20	0.66
18W	23	17	86	0.69	-0.40	0.57	0.80	1.94	0.25	-0.4	2.7	-3.7	0.60	0.21	0.54
19M	24	15	87	0.90	-0.68	0.66	0.76	0.69	3.70	-0.4	-1.0	5.7	0.59	0.60	0.78
20M	25	25	99	1.11	0.74	1.90	0.50	0.90	0.92	-1.1	-0.2	-0.2	0.67	0.53	0.32

Person	TOTAL SCORE			JMLE MEASURE			Outfit MNSQ			Outfit ZSTD			PT Measure-Corr		
	KA	SA	AA	KA	SA	AA	KA	SA	AA	KA	SA	AA	KA	SA	AA
21W	23	26	111	0.69	0.90	3.59	2.27	0.55	0.89	2.5	-1.6	-0.2	0.40	0.74	0.55
22W	24	25	102	0.90	0.74	2.27	0.80	0.58	0.69	-0.3	-1.5	-1.3	-0.57	0.70	0.65
23W	22	22	93	0.49	0.30	1.24	1.08	0.91	0.36	0.3	-0.3	-3.0	0.55	0.57	0.70
24W	22	19	98	0.49	-0.12	1.79	0.71	0.72	0.45	-0.8	-1.1	-2.6	0.70	0.62	0.63
25W	22	22	106	0.49	0.30	2.80	0.72	0.64	1.84	-0.7	-1.5	2.7	0.66	0.68	0.51
26W	22	20	92	0.49	0.02	1.14	0.98	0.74	1.00	0.1	-1.1	0.1	0.58	0.62	0.06
27W	25	18	96	1.11	-0.26	1.56	1.21	0.79	0.76	0.6	-0.8	-0.9	0.51	0.58	0.49
MEAN	22	20.7	95.9	0.50	0.13	1.80	1.00	1.01	1.00	0.00	0.00	-0.5			
P.SD	2.9	4.7	10.7	0.59	0.67	1.56	0.49	0.42	0.81	1.2	1.2	2.4			

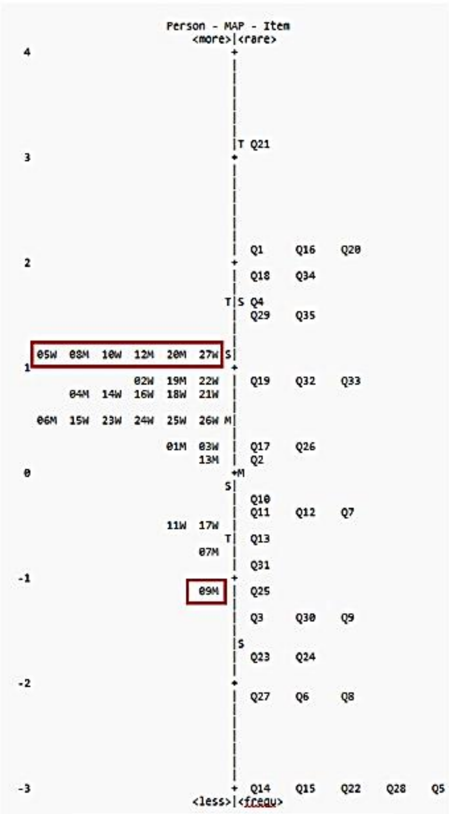

Figure 1. Wright Map Knowledge Aspects

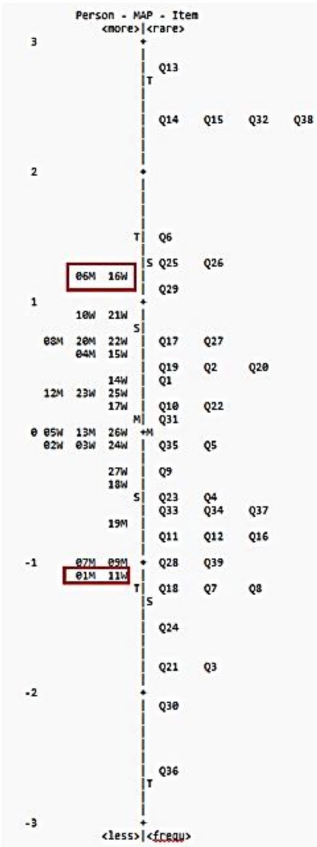

Figure 2. Wright Map Skills Aspects

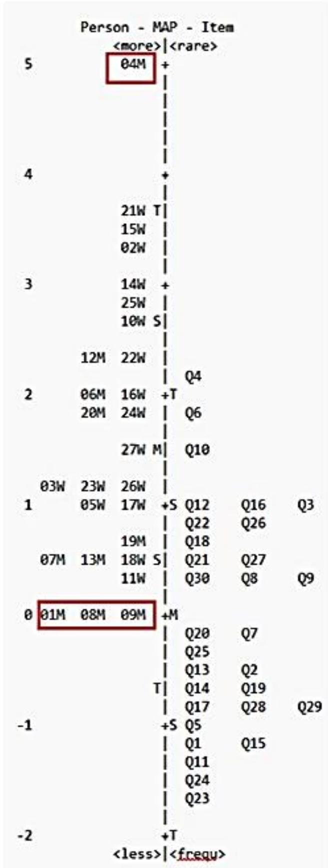

Figure 3. Wright Map Attitide Aspects

Figure 1 illustrates that the mean of the knowledge aspect items is positioned one scale line above 0. while the mean person score is one above 0. This suggests that the physics teachers' ability to answer knowledge-related SIL questions has an average logit value higher than the logit values of the items. The logit ruler identifies Q21 as the most challenging item. with incorrect responses from the teachers. Furthermore. items Q1. Q16. and Q20 received very few correct answers. Items that are closest to the mean (M) on the logit ruler. such as Q2 (near M from the top of the Wright Map) and Q10 (near M from the bottom). help differentiate teachers with higher and lower abilities. The Wright Map shows that two teachers 07M and 09M are positioned outside the standard deviation limits (T). with the lowest logit values. indicating the lowest SIL in the knowledge aspect.

Conversely. six teachers. 05W. 08M. 10W. 12M. 20M. and 27W. hold the highest logit values. indicating the highest SIL in the knowledge aspect. Overall. most physics teachers are categorized within the -1 to 1 range on the logit ruler.

Figure 2 demonstrates that the mean of the skill aspect items is positioned one scale line above 0. while the mean person score is 1 above 0. This indicates that the physics teachers' ability to answer skills-related SIL questions has an average logit value that exceeds the logit values of the items. The logit ruler marks Q12 as the most difficult item. with incorrect responses from the teachers. Additionally. items Q14. Q15. Q32. and Q38 received very few correct answers. Items closest to the mean (M) on the logit ruler. including Q31 (near M from the top of the Wright Map) and Q35 and Q5 (near M from the bottom). are effective in distinguishing between teachers with higher and lower abilities. The Wright Map shows two teachers. 01M and 11W. who possess the lowest logit values. reflecting the lowest SIL in the skills aspect. On the other hand. two teachers. 06M and 16W. have the highest logit values. indicating the highest SIL in the skills aspect. Most physics teachers are categorized within the -1 to 1 range on the logit ruler.

Figure 3 reveals that the mean of the attitude aspect items is four scale lines above 0. while the mean person score is 1 above 0. This suggests that the physics teachers' ability to answer attitude-related SIL questions has an average logit value greater than the logit values of the items. The logit ruler identifies Q4 as the most difficult item. yet the teachers answered it correctly. Items closest to the mean (M) on the logit ruler. such as Q30. Q8. and Q9 (near M from the top of the Wright Map) and Q20 and Q7 (near M from the bottom). help distinguish teachers with higher and lower abilities. The Wright Map shows one teacher. 04M. with the highest logit value. indicating the highest SIL in the attitude aspect. In contrast. three teachers 01M. 08M. and 09M are positioned with the lowest logit values. indicating the lowest SIL in the attitude aspect. Most physics teachers are categorized within the 0 to 4 range on the logit ruler. Based on the Wright Map. the profiles of physics teachers' scientific inquiry literacy in the knowledge. skills. and attitude aspects are summarized in Table 9.

Table 9. The profile of physics teachers' scientific inquiry literacy for each aspect

Aspects	Category	Teachers' Code
Knowledge	High	05W. 08M. 10W. 12M. 20M. and 27W
	Moderate	02W. 19M. 22W. 04M. 14W. 16W. 18W. 21W. 06M. 15W. 23W. 24W. 25W. 26W. 01M. 03W. 13M. 11W. 17W. 07M
	Low	07M and 09M
Skills	High	06M and 16W
	Moderate	10W. 21W. 08M. 20M. 22W. 04M. 15W. 14W. 12M. 23W. 25W. 17W. 05W. 13M. 26W. 02W. 03W. 24W. 27W. 18W. 19M. 07M. 09M
	Low	01M and 11W
Attitude	High	04M
	Moderate	21W. 15W. 02W. 14W. 25W. 10W. 12M. 22W. 06M. 16W. 20M. 24W. 27W. 03W. 23W. 26W. 05W. 17W. 19M. 07M. 13M. 18W.
	Low	11W. 01M. 08M. and 09M

The average SIL of physics teachers in West Java is relatively high. as indicated by the Wright Map outputs generated using the Rasch model. The person mean scores across the knowledge. skills. and attitude aspects are all located above the item mean values. suggesting that the teachers' performance generally exceeds the difficulty levels of the SILI items. This finding reflects positively on the overall scientific inquiry literacy of the participating in-service teachers. However. a closer inspection of the Wright Maps reveals a mismatch between teacher abilities and item difficulties. Specifically. many teachers are clustered at the upper end of the ability continuum. while a large proportion of the items are positioned on the lower end of the difficulty scale.

According to Rasch literature. a mismatch between teacher ability and item difficulty may indicate a ceiling effect. where the instrument lacks the precision to distinguish high-performing participants (Boone & Staver. 2020; Davis & Boone. 2021). Finger. as cited in Davis & Boone (2021). considers targeting suboptimal when the difference between the average person and item measure exceeds 1.00 logits. In this study. the person–item mean differences were 1.24 logits for the knowledge aspect. 0.87 logits for skills. and 0.70 logits for attitude. with over 20% of participants in each aspect reaching the highest ability levels. Fisher proposed that these values exceed the ceiling effect threshold of 5% (Davis & Boone. 2021). suggesting that the instrument may not provide sufficient measurement precision for high-performing participants. This indicates the need to revise the SILI instrument by increasing item difficulty for better discrimination.

Beyond overall patterns. the Wright Maps also revealed individual profiles that warrant further investigation. Substantial variability in teacher abilities may be linked to differences in experience. professional development. or pedagogical beliefs (Correia & Harrison. 2020). For instance. facilitators tend to apply more open-ended inquiry approaches. while directive-oriented teachers may limit student autonomy. affecting inquiry integration. Such disparities often challenge the implementation of inquiry during planning. instruction. and evaluation (Haynes et al.. 2023).

These findings underscore the value of combining Rasch analysis with qualitative methods such as observations. interviews. and teaching artifact analysis to gain deeper insights into the contextual factors shaping teacher inquiry literacy. Furthermore. research into the impact of sustained. reflective professional development can inform strategies for strengthening inquiry-based teaching in diverse settings (Haynes et al.. 2023).

Knowledge Aspect

The Knowledge Aspect (KA) had a person measure value of 0.50. which shows that the average score of the teachers in this area is slightly above the difficulty level of the questions. This suggests that. in general. teachers' knowledge of scientific inquiry aligns well with the level of complexity of the questions posed. Research indicates that teachers with a more developed understanding of scientific inquiry tend to incorporate more inquiry elements and higher-order questioning in their lesson plans.

For example. teachers who improved their views about scientific inquiry through professional development were more likely to include complex scientific inquiry elements in their lesson plans. suggesting a relationship between their knowledge and the complexity of questions they pose to students (Cigdemoglu & Köseoğlu. 2019). Furthermore. teacher training and explicit reflection on the nature of scientific inquiry have been shown to enhance teachers' ability to pose more complex. researchable questions. For instance. engaging teachers in laboratory-based inquiry activities and microteaching presentations helps them develop a more coherent understanding of scientific practices. which is reflected in the sophistication of the questions they pose during instruction (Ann Haefner & Zembal-Saul. 2004; Özer & Sarıbaş. 2023). However. some studies also note that there can be a gap between teachers' conceptual knowledge of inquiry and their classroom practice. with some teachers struggling to translate their understanding into complex. inquiry-driven questioning in real classroom settings (Bartos & Lederman. 2014). This highlights the importance of ongoing professional development and reflective practice to ensure alignment between knowledge and practice.

However. a closer look at specific items reveals that certain questions (e.g.. Q21. Q1. Q16. and Q20) were particularly challenging for the teachers. with very few correct responses. This points to possible gaps in the teachers' understanding of specific scientific inquiry concepts or areas where further training is needed. The fact that teachers struggled with question Q21. which required recognizing and evaluating alternative explanations when encountering unexpected results. reflects higher-order reasoning. Q1 tested the ability to accurately sequence steps in an experimental procedure. highlighting procedural understanding. Q16 assessed the skill of concluding graphical data. and Q20 involved constructing and revising explanations based on evidence and logic. These tasks reflect cognitively demanding aspects of inquiry where difficulties may stem from gaps in conceptual understanding and limited experience with authentic inquiry. Prior studies confirm that science teachers often struggle with abstract inquiry concepts such as data interpretation. hypothesis generation. or differentiating between observation and inference. even after formal training (Baykara et al.. 2018; Kan et al.. 2024).

This pattern is not unique to this study. as previous research has also highlighted persistent challenges teachers face in mastering complex inquiry concepts. even after professional development. Research consistently shows that teachers often have inadequate or naïve understandings of specific aspects of scientific inquiry. even after some training. and that focused professional development explicitly addressing challenging concepts can help close these gaps (Adisendjaja et al.. 2017; Özer & Sarıbaş. 2023; Stylos et al.. 2023; Zion et al.. 2020).

To address these gaps. studies suggest that teachers' understanding improves when they experience inquiry as a dynamic. open-ended process. which supports deeper comprehension of difficult concepts (Zion et al.. 2020). Additionally. teachers tend to default to simpler inquiry methods and may not fully integrate complex elements into their teaching without structured frameworks and ongoing support (Cigdemoglu & Köseoğlu. 2019). Reflective tools. such as knowledge structure mapping. can help teachers identify gaps and misconceptions. particularly in dealing with complex or abstract concepts (Bartos & Lederman. 2014; Özer & Sarıbaş. 2023). Furthermore. engaging teachers in authentic investigations and collaborative inquiry projects has been shown to strengthen their understanding and better equip them to address challenging concepts in the classroom (Ann Haefner & Zembal-Saul. 2004).

Teachers with the highest logit values (e.g.. 05W. 08M. 10W. 12M. 20M. 27W) demonstrated stronger knowledge in scientific inquiry. while those with lower values (e.g.. 07M. 09M) showed areas for improvement. Targeted professional development is needed to address these gaps. focusing not only on content knowledge but also on pedagogical content knowledge to support effective teaching (Van Driel & Berry. 2012). The effectiveness of such programs depends on both their design and the pedagogies used to help teachers integrate new knowledge into classroom practice (Kennedy. 2016). Aligning professional development with daily instruction and providing opportunities for reflection and application can support more meaningful and sustained improvements. particularly for teachers with lower performance in the knowledge aspect.

Skills Aspect

The Skills Aspect (SA) had a person measure value of 0.13. indicating that physics teachers generally performed slightly above the difficulty level of the items. However. their skills in scientific inquiry may not be as strong as their knowledge. This suggests that although teachers may understand the theoretical aspects of scientific inquiry. they may struggle with applying those concepts in practice.

Specific questions. such as Q12. Q14. Q15. Q32. and Q38. were noted as particularly difficult. with many teachers providing incorrect responses. These items likely assess practical application or procedural knowledge of scientific inquiry. which may require more hands-on experience or specific pedagogical training.

Teacher Performance: two teachers (06M and 16W) had the highest scores in the skills aspect. suggesting that they possess better practical application skills. In contrast. teachers like 01M and 11W scored poorly. indicating a need for professional development in areas related to the skills of scientific inquiry. including experiment design. data analysis. or inquiry-based teaching strategies.

This finding aligns with previous studies showing that physics teachers often understand theoretical aspects of inquiry but struggle with its practical implementation in classrooms (Bartos & Lederman. 2014; Şengül. 2024). Teachers have shown low performance in skills such as designing experiments. analyzing data. and conducting investigations. consistent with patterns observed in items Q12. Q14. and Q38. To address these gaps. research recommends hands-on professional development focused on experimental design. data analysis. and inquiry-based strategies to strengthen teachers' practical competencies. The variability in teacher performance further highlights the need for differentiated training that targets specific skill gaps and incorporates reflective practice to improve both understanding and application of scientific inquiry (Darman. Suhandi. Kaniawati. & Samsudin. 2024; Saputra et al.. 2019).

Attitude Aspect

The Attitude Aspect (AA) had the highest person measure value of 1.57. indicating that. overall. physics teachers in West Java show a positive attitude toward scientific inquiry. In addition to the high person measure. the person reliability for the AA was also the highest among the three aspects at 0.87. suggesting a consistent pattern of positive responses from participants. This is a promising finding. as it suggests that teachers generally recognize the importance of scientific inquiry and are open to incorporating inquiry-based methods into their teaching. However. the items associated with the attitude aspect still reveal some variability in teachers' responses. For instance. Q4 was the most difficult item in this aspect. even though teachers answered it correctly. This suggests that certain aspects of scientific inquiry may be more abstract or less well-understood. which could affect teachers' attitudes toward implementing inquiry-based methods. Research suggests that such variability in responses may stem from the abstract or less familiar nature of specific inquiry concepts. and that explicit instruction and reflection on the structure and connections within scientific inquiry can help clarify these challenging aspects and promote more consistent positive attitudes across all components of inquiry (Bartos & Lederman. 2014).

Teacher Performance: Teacher 04M had the highest score in the attitude aspect. demonstrating a strong commitment to inquiry-based teaching. while teachers such as 01M. 08M. and 09M had lower scores. indicating that their attitudes toward scientific inquiry may not be as positive. These teachers might benefit from professional development that focuses not only on the practical and theoretical aspects of scientific inquiry but also on fostering a mindset that values student-centered. inquiry-based teaching approaches.

Studies have shown that targeted professional development—such as intensive workshops that address the nature of science and inquiry. and provide opportunities to design and implement inquiry-based lessons—can significantly improve teachers' attitudes and understanding of scientific inquiry (Cigdemoglu & Köseoğlu. 2019). Nevertheless. research has also found that teachers with positive attitudes toward inquiry often do not fully implement inquiry-based methods in their classrooms. reflecting a persistent gap between attitude and practice (Bartos & Lederman. 2014; Şengül. 2024). Therefore. ongoing. structured professional development that explicitly helps teachers bridge this gap is essential to ensure that positive attitudes are effectively translated into inquiry-based teaching practice. Additionally. engagement in authentic. experiential science activities such as partnerships with scientists or participation in real-world inquiry projects has been shown to produce significant positive shifts in teachers' attitudes and pedagogical choices. making them more likely to adopt inquiry-based approaches in their classrooms (Houseal et al.. 2014).

Additionally. while engagement in authentic. experiential science activities can initiate positive shifts. sustained support is necessary to ensure these changes are maintained and expanded in practice. Teachers' attitudes and self-efficacy are crucial to the successful implementation of scientific inquiry in the classroom. Teachers with higher self-efficacy and positive attitudes are more likely to adopt and sustain inquiry-oriented practices. while those with lower confidence may require targeted interventions to overcome potential barriers (Herrington et al.. 2016; Kaya et al.. 2021; Thibaut et al.. 2018). This support can be provided through motivational workshops. structured discussions on the benefits of scientific inquiry. and the creation of communities of practice among teachers who can share experiences. strategies. and mutual encouragement (Gale et al.. 2022; Herrington et al.. 2016).

Beyond building supportive communities. it is equally important to establish mechanisms for ongoing monitoring and reflection. Continuous monitoring of teachers' scientific inquiry literacy can further help track progress and identify areas where additional support is needed. Regular assessments and feedback loops are essential for refining teachers' skills and improving both teacher and student engagement in science education (Chi et al.. 2021; Thibaut et al.. 2018). This ensures that teachers are continually improving and aligning their knowledge. skills. and attitudes with the evolving needs of science education.

▪ CONCLUSION

The results indicate that while the overall scientific inquiry literacy (SIL) of physics teachers in West Java is relatively high. there remain notable areas for improvement across the knowledge. skills. and attitude dimensions. Targeted professional development is needed to strengthen teachers' conceptual understanding. inquiry skills. and attitudes toward inquiry-based instruction. supported by sustained mentoring and reflective practice. However. these findings should be interpreted with caution due to methodological limitations. including the use of non-probability sampling and a relatively small sample size. which may affect generalizability. Future research should not only evaluate the long-term impact of such professional development but also examine how enhanced teacher inquiry literacy contributes to fostering scientifically literate. critically thinking. and innovative younger generations capable of addressing real-world challenges through inquiry and evidence-based reasoning.

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