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CRITICAL THINKING DEVELOPMENT IN PHYSICS EDUCATION THROUGH THE IMPLEMENTATION OF THE BW-EXPORT MODEL AT MADRASAH ALIYAH

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ABSTRACT
Physics practicum activities in Madrasah Aliyah (MA) require learning models that not only strengthen students' cognitive skills but also integrate character values aligned with Islamic education. This study aims to develop and evaluate the BW-ExPort (Based–Writing–Experimental Report) learning model to improve students' critical thinking skills during physics practicum activities in MA. Using a Research and Development (R&D) design, the study proceeded through three stages: preliminary study, model development, and field testing. The participants consisted of 82 eleventh-grade students from two MA in North Maluku. Data were gathered through expert validation, classroom observation, and critical thinking assessments, and analyzed using the Rasch model with stacking and racking techniques. Stacking analysis via the Wright Map revealed a clear increase in student ability, shifting from pre-test logits (–3 to 0) to post-test logits (0 to +3), with one student reaching +4. Interpretation and explanation items became easier after the intervention, while evaluation and inference items remained comparatively difficult, indicating the need for additional scaffolding. Racking analysis further confirmed increased item ease, suggesting improved mastery. The BW-ExPort model is valid, practical, and effective in strengthening students' critical thinking during physics practicum activities. By integrating Islamic scientific ethics such as honesty and responsibility, BW-ExPort offers a culturally grounded and impactful model for digital-based science learning that supports both cognitive growth and character development in Islamic educational settings.

Keywords: BW-ExPort Model, Critical Thinking, Madrasah Aliyah, Physics Education,

INTRODUCTION
The global transformation of 21st-century education requires a paradigm shift in science learning, from teacher-centred and passive instruction to interactive, reflective, and digitally integrated pedagogical approaches. The rapid advancement of digital technologies has created new opportunities to establish collaborative and inquiry-based learning environments that foster deeper conceptual understanding and critical thinking (Simbolon et al., 2025; Gunawan et al., 2023; Sampson et al., 2011). In physics education, particularly for abstract topics such as direct current electricity, the integration of digital tools is essential to bridge theoretical knowledge with concrete, student-centred experiences. Digital media not only facilitate the visualization of scientific concepts but also support student engagement and strengthen scientific documentation practices. According to data from the OECD in 2023, digitally enriched

instruction is not merely a trend but a strategic necessity for equipping students with higher-order thinking skills relevant to the challenges of the 21st century.

Despite these opportunities, many physics classrooms still rely on procedural and outcome-based practices that constrain student reasoning, conceptual elaboration, and reflective analysis (Balulu et al., 2023). Students are often asked to conduct experiments and record outcomes without adequate guidance in interpreting data or constructing scientific explanations. As a result, Indonesian students have consistently scored low on international assessments such as PISA and TIMSS, particularly in scientific reasoning, critical thinking, and scientific writing (Admoko et al., 2021; Lenkeit et al., 2015). This gap is further exacerbated by the limited integration of digital literacy and by teachers' lack of pedagogical support, especially in guiding students to develop structured, reflective scientific reports (Kusumawati et al., 2020; Lembke et al., 2021).

Scientific report writing plays a strategic role in science education, as it promotes not only the documentation of procedures and results but also students' ability to analyze, evaluate, and construct arguments based on empirical evidence (Larkin, 2019; Mah et al., 2021). Well-structured scientific writing facilitates deeper learning and enables students to connect experimental results to theoretical concepts. However, current pedagogical practices often fail to integrate scientific reporting effectively into learning processes, resulting in a fragmented understanding and low levels of critical engagement.

Several instructional models, such as the Science Writing Heuristic (SWH) and Argument-Driven Inquiry (ADI), have been developed to enhance students' critical thinking and scientific writing skills. SWH encourages reflective writing during inquiry, while ADI emphasizes data-based argumentation. However, both models face limitations in integrating scientific writing with critical reasoning in a digital format (Çetin & Eymur, 2017; Cronje et al., 2013; Hand et al., 2022). For example, SWH lacks structured scaffolding for critical reasoning (Hike & Hughes-Phelan, 2020), whereas ADI prioritizes argumentation at the expense of report coherence and organization (Bonham et al., 2018). Additionally, the lack of teacher preparedness and digital integration further hinders their application in physics classrooms (Çikmaz, 2014; Cronje, 2013).

To address these gaps, this study introduces the BW-ExPort (Based–Writing–Experimental Report) learning model, which combines experimentation, critical thinking, and digital scientific writing. The model consists of structured stages, including the problem formulation stage. Based on experimentation, data analysis, and digital report writing using Canva Docs. This platform supports collaborative, visual, and interactive writing, enabling students to integrate diagrams, graphs, and narrative text into their experimental reports. Such integration enhances engagement and supports systematic reflection, thus strengthening students' scientific reasoning.

From an Islamic education perspective, the development of intellectual virtues, reason (*'aql*), reflection (*tafakkur*), and pursuit of knowledge (*'ilm*), has a strong foundation in the Qur'an and Hadith. Verses such as Surah Al-Baqarah [2]:269 and Az-Zumar [39]:9 emphasize the importance of wisdom and knowledge as essential values in human development. These principles provide a spiritual and epistemological foundation for integrating scientific inquiry with Islamic ethical values, such as honesty, accountability, and responsibility (Yumesri et al., 2024).

Therefore, the purpose of this study is to develop and evaluate the BW-ExPort model, integrated with Canva Docs, to enhance students' critical thinking skills in MA physics classes. This research offers a pedagogical innovation that addresses current gaps in digital literacy, scientific writing, and critical reasoning, while aligning science instruction with Islamic values and 21st-century educational goals.

METHOD

This study employed a Research and Development (R&D) approach, adapting the procedural framework of Borg and Gall, which consists of three main stages: preliminary study, model development, and model testing. The preliminary study involved literature reviews and field observations at two Madrasah Aliyah in North Maluku to identify the need for an instructional model that integrates digital scientific reporting with critical thinking enhancement. During model development, a Focus Group Discussion (FGD) was conducted with experts in physics education to design the theoretical components of the BW-ExPort model, including syntax, learning principles, and social system. Supporting materials, including a syllabus, lesson plans, student worksheets, a Canva Docs-based digital experimental report format, and a critical thinking assessment, were developed and validated by three content experts. The field test involved 82 Grade XI science students who had not previously received instruction on scientific report writing or critical thinking training. The data sources consisted of validation forms, teacher observation sheets, and critical thinking tests administered both before and after the intervention. The data types included qualitative judgments from experts, observational records, and quantitative test scores. Data analysis was conducted in two main dimensions: practicality and effectiveness. Practicality was assessed descriptively through teacher observations of implementation quality and student engagement. Effectiveness was measured using the Rasch Model with stacking and racking techniques. Stacking analysis allowed for longitudinal mapping of students' critical thinking abilities by combining pre-test and post-test data into a single logit scale, while racking analysis compared item difficulties across both tests to identify changes in cognitive challenge per indicator (Isnawati et al., 2024; Laliyo et al., 2022; Sumintono & Widhiarso, 2013). The Winsteps software was used for all Rasch analyses to ensure precise calibration, reliable measurement, and visual interpretation of learning gains.

RESULTS AND DISCUSSION

Results of BW-ExPort Model Development and Validation

The BW-ExPort (Based–Writing–Experimental Report) learning model was developed as a pedagogical innovation to address the limitations of two previous models: the Science Writing Heuristic (SWH) and Argument-Driven Inquiry (ADI). This model was specifically designed to integrate critical thinking skills and digital-based experimental report writing using the Canva Docs platform. The BW-ExPort syntax was constructed through theoretical and empirical synthesis, considering instructional time efficiency, the effectiveness of scientific skills development, and the relevance of digital integration in 21st-century physics education.

The first phase of the BW-ExPort model is problem identification, which adapts the initial stage of the SWH and ADI models. In this stage, students are trained to activate prior knowledge, independently identify problems, and relate them to real-life phenomena and Islamic values such as *tadabbur* (contemplation) of Allah's creation. The second phase focuses on conducting experiments and processing data, either in the laboratory or through digital simulations. The third phase emphasizes individual, argument-based scientific report writing using Canva Docs. The fourth phase involves elaborative, data-driven discussions to foster analytical and evaluative thinking. The final phase involves writing a reflective final report, enriched with feedback from teachers and peers, that covers comprehensive indicators of critical thinking.

The structure of this model has been simplified to accommodate the 90-minute instructional time per session, as regulated in the Indonesian National Curriculum. This simplification eliminates repetitive processes, such as prolonged negotiation and revision phases, commonly found in the SWH and ADI models (Cronje, 2013; Katchevich et al., 2013), thereby ensuring instructional efficiency without compromising the quality of students' scientific thinking development.

The BW-ExPort model is also embedded with Islamic educational values, such as *ukhuwah ilmiah* (scientific brotherhood) during discussions, *amanah* (responsibility) in reporting experimental results, and adab *al-'ilm* (ethics in seeking and disseminating knowledge) at every stage of learning. This emphasis on scientific ethics aligns with the Qur'anic verse in Surah Al-Mujadilah [58]:11, "Allah will raise those who have believed among you and those who were given knowledge, by degrees," affirming that the pursuit of knowledge should be carried out with sincerity and responsibility.

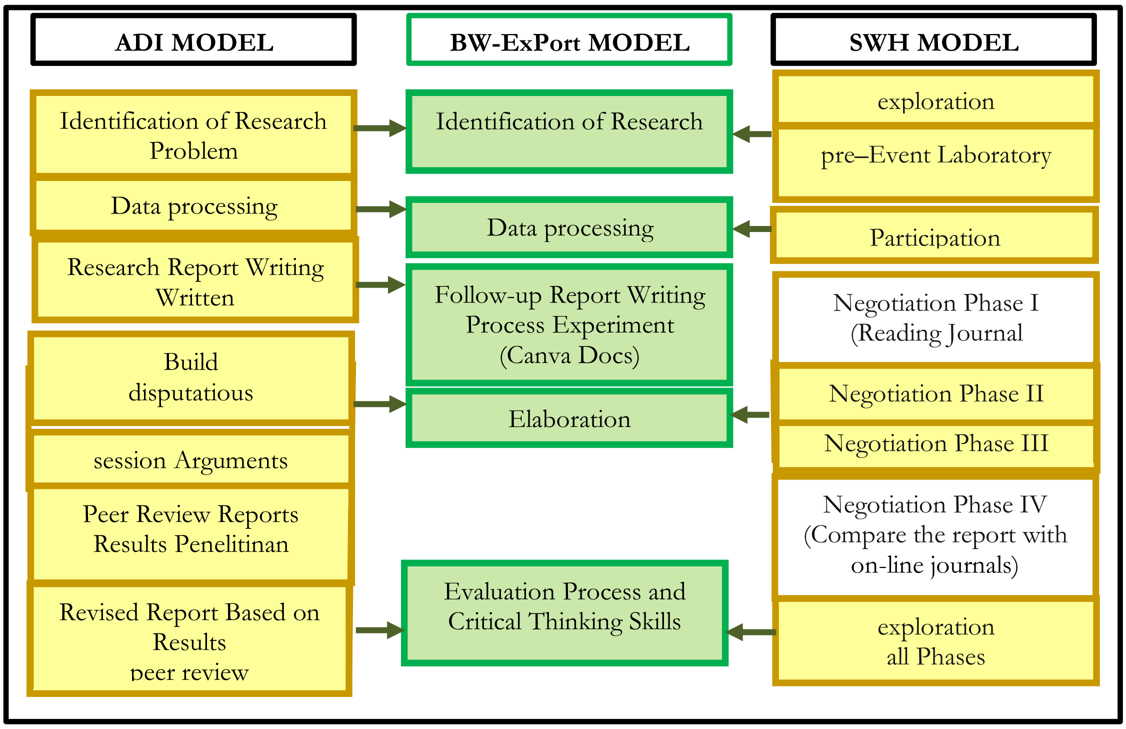


Figure 1. The results of the development of the BW-ExPort teaching model from the SWH and ADI learning models.

Three physics education experts evaluated the content and construct validity of the BW-ExPort model. Content validity reflects the extent to which the model's components comprehensively address the conceptual domains being developed, while construct validity assesses the alignment between the foundational theory and its practical implementation. The results of the evaluation are presented in Table 1 below:

Table 1. Results of content validation assessment and construct validity of the BW-ExPort Model

No	Assessment Aspects	Validation score	Validation criteria	Reliability Coefficient	Reliability
A	**Content validity**				
1	Model Overview	4.22	Very Valid	96.00%	Reliable
2	BW-ExPort Model Requirements	4.33	Valid	88.89%	Reliable
3	Current state of knowledge	4.28	Very Valid	92.31%	Reliable
4	Theoretical Support of the BW-ExPort Model	4.33	Very Valid	94.12%	Reliable

No	Assessment Aspects	Validation score	Validation criteria	Reliability Coefficient	Reliability
5	Implementation of the BW-ExPort model	4.17	Very Valid	87.50%	Reliable
6	BW-ExPort model learning environment	4.50	Very Valid	100.00%	Reliable
B	**Construct Validity**				
1	BW-ExPort Learning Model Overview	4.50	Very Valid	88.89%	Reliable
2	Theoretical and empirical support for the BW-ExPort model	4.26	Very Valid	85.10%	Reliable
3	Sintaks Model BW-ExPort	4.50	Very Valid	88.89%	Reliable
4	Social systems	4.17	Very Valid	90.98%	Reliable
5	Principle of reaction	4.33	Very Valid	90.87%	Reliable
6	Learning environment and classroom management	4.33	Very Valid	88.89%	Reliable
7	Evaluation implementation	4.67	Very Valid	88.89%	Reliable

The validation results indicate that all components were rated as "very valid" by the experts, with reliability coefficients exceeding the minimum threshold of 75%, demonstrating strong inter-rater consistency. Thus, the BW-ExPort model is theoretically and practically viable for use in 21st-century physics education integrated with Islamic values. Supporting instructional tools, including the syllabus, lesson plans, student books, worksheets, and digital report format via Canva Docs, as well as critical thinking skills assessment sheets, were also validated. All components were rated highly valid and reliable (Table 2), reinforcing the consistency between the model design and its supporting instructional instruments.

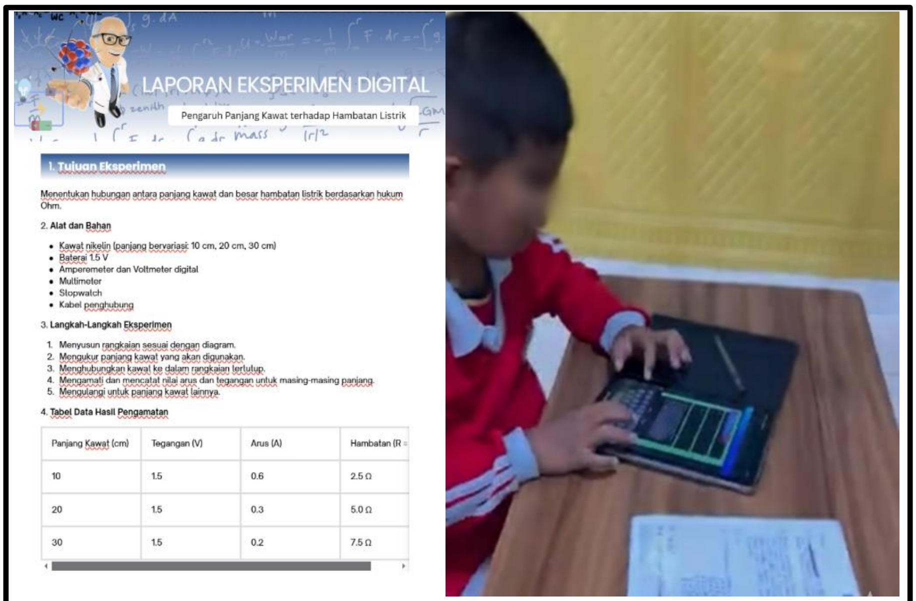
Table 2. Expert Validation Results of BW-ExPort Instructional Materials

No	Content	Average total	Validation criteria	Reliability Coefficient	Reliability
1	Syllabus	4.29	Very Valid	86.69%	Reliable
2	lesson plan	4.35	Very Valid	88.16%	Reliable
3	Student Books	4.31	Very Valid	94.63%	Reliable
4	Student worksheets	4.16	Very Valid	90.25%	Reliable
5	Experimental Report Writing Format	4.44	Very Valid	90.21%	Reliable
6	Critical Thinking Skills Assessment Sheet	4.60	Very Valid	98%	Reliable

The expert validation results show that the BW-ExPort model possesses high content and construct validity. The practicality and effectiveness evaluations in madrasah settings demonstrate that this model is not only efficiently implementable but also significantly improves students' critical thinking skills. These findings align with the existing literature, which highlights the substantial contribution of scientific writing activities to the development of analytical and conceptual thinking (Greenbowe et al., 2007; Xu & Talanquer, 2013).

One of the model's key strengths is its integration of Canva Docs, which allows students to compose digital experimental reports interactively and reflectively. Figure 2 presents an example of a student's digital report on the topic "The Effect of Wire Length on Electrical Resistance." Through this approach, the BW-ExPort model becomes not only a pedagogical solution for enhancing critical thinking skills but also a medium for spiritual and academic transformation that reflects the integration of faith (*iman*), knowledge (*'ilm*), and action (*'amal*) in modern science education.

Pedagogically and socially, the BW-ExPort model fosters active interaction between teachers and students, as well as peer collaboration. The elaboration phase, in particular, provides a space for meaningful discussion and reflective thinking (Roberts et al., 2014; Wu et al., 2023). The model also supports the use of virtual laboratories to address infrastructure limitations (Hofstein & Mamlok-Naaman, 2007).



(a) (b)

Figure 2 (a). Digital experiment report (b). Student's engagement with the worksheet

Figure 2 (a) shows the digital experiment report produced through the BW-ExPort model, which organizes the practicum into clear sections, objectives, materials and tools, procedural steps, and an observation table for recording experimental data. This structured digital format guides students in documenting their work systematically and supports the development of scientific reasoning. Figure 2(b) depicts students actively completing the experiment worksheet, illustrating their engagement in observing, recording, and discussing the results. The scene highlights the BW-ExPort model's emphasis on collaborative, inquiry-based learning and its role in strengthening both cognitive and procedural skills during physics practicum activities.

Practicality of BW-ExPort Model Implementation Based on Islamic Values

The practicality of the BW-ExPort model was evaluated through direct classroom observations in two partner Madrasah Aliyah. The evaluation focused on five core instructional activities according to the BW-ExPort syntax: (1) problem identification, (2) data processing, (3) report writing using Canva Docs, (4) elaboration, and (5) final evaluation. Each stage was observed by two physics teachers using a validated observation sheet. The assessment included the fluency of implementation, student engagement, and alignment with the BW-ExPort instructional design.

The results showed that all learning activities were conducted smoothly, with high average scores and inter-observer agreement (R) exceeding 95%. The highest scores were found in the evaluation and experimental report writing activities using Canva Docs. This platform not only facilitated scientific documentation but also fostered collaborative spirit and student independence in presenting experimental results visually and systematically.

Table 3. Practicality Results from BW-ExPort Model Implementation

No	Activity	Lesson Plan 1 (Ohm's Law)	Lesson Plan 2 (Series & Parallel Circuits)	Lesson Plan 3 (Kirchhoff's Laws I & II)
		Madrasah 1 / Madrasah 2	Madrasah 1 / Madrasah 2	Madrasah 1 / Madrasah 2
1	Identify the problem	3.18 (97.14%) / 3.00 (83.33%)	3.78 (97.06%) / 3.56 (100%)	4.00 (100%) /3.86 (96.30%)
2	Data processing	3.25 (97.44%) / 3.08 (97.30%)	3.56 (98.25%) / 3.75 (100%)	3.94 (98.59%) /3.86 (96.30%)
3	Follow-up Report Writing (Canva Docs)	3.00 (83.33%) / 3.00 (100%)	3.50 (100%) / 3.25 (92.31%)	4.00 (100%) / 4.00 (100%)
4	Elaboration	3.08 (97.30%) / 3.05 (95.14%)	3.18 (97.14%) / 3.17 (100%)	3.83 (95.65%) / 4.00 (100%)
5	Evaluation	3.17 (100%) / 3.06 (98%)	3.75 (93.33%) / 3.18 (97.14%)	3.92 (97.87%) / 4.00 (100%)

Table 3 demonstrates that the BW-ExPort model is efficient and can be consistently implemented across various madrasah learning contexts. The use of Canva Docs as a platform for scientific reporting also received positive responses from both teachers and students. It helped students structure their reports more interactively and visually, thereby enhancing digital literacy and scientific communication skills.

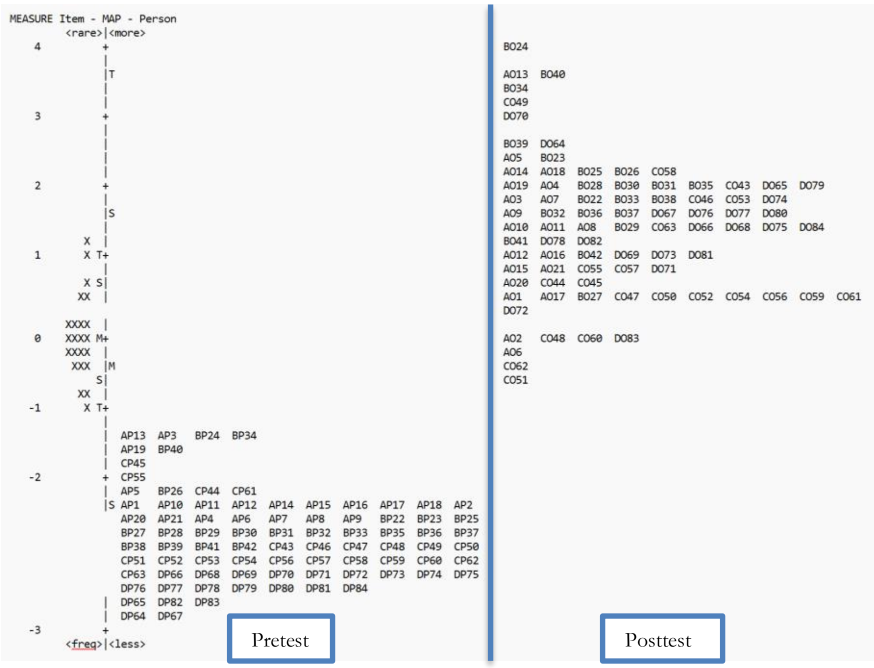
In madrasah implementation, Islamic values such as scientific trustworthiness (*amanah*), honesty in data reporting, and *ukhuwah ilmiah* in group discussions were emphasized through this model. Teachers emphasized that presenting honest experimental findings is a fundamental aspect of the scientific ethics taught in Islam, as reflected in the Quran. Al-Hujurat verse 6: "O you who have believed, if there comes to you a disobedient one with information, investigate..." This verse emphasizes the principle of verification and honesty in conveying scientific information. Moreover, group discussions were directed to serve as platforms for building brotherhood, listening respectfully, and valuing opinions, in line with QS. Al-Mujadilah verse 11 about honoring those with knowledge. Overall, these findings show that the BW-ExPort model is not only practical but also supports the integration of Islamic values into science learning in madrasah. It strengthens the unity of faith (*iman*), knowledge (*'ilm*), and action (*'amal*) in the learning process, positioning itself as a comprehensive approach that cultivates 21st-century skills while nurturing noble character in students.

Effectiveness of the BW-ExPort Model (Rasch Stacking and Racking Analysis)

The implementation of the BW-ExPort instructional model across four classes at two MA demonstrated significant effectiveness in enhancing students' critical thinking skills. The analysis employed the Rasch Model, utilizing two distinct techniques: stacking analysis, which examines shifts in student abilities, and racking analysis, which monitors changes in item difficulty levels based on critical thinking indicators.

The stacking analysis results, visualized through the Wright Map, revealed a substantial shift in student logit scores before and after the implementation of the BW-ExPort model. During the pre-test phase, the majority of students from the four classes were categorized at the lower end of the ability spectrum, with logit scores ranging from -3 to 0. However, after the BW-ExPort intervention, student distribution shifted significantly to the 0 to +3 range, with one student in Class A (Madrasah 1 – Physics 1) exceeding a +4 logit score. In particular, students at Madrasah 1 showed a transition from negative logits to the +1 to +3 range, indicating a marked improvement in critical thinking skills. Similarly, at Madrasah 2, students shifted from initial logits of -2 or -3 to a range of 0 to +2.5. This progression indicates a tangible and measurable impact of the BW-ExPort model in fostering students' critical thinking.

The nature of this shift can be more effectively understood through the Wright Map, as shown in Figure 3. By plotting item difficulty alongside respondent ability, the map provides a comprehensive representation of how the observed patterns are distributed across the measurement scale.



Note:
Code A: Madrasah 1 – Physics 1, Code B: Madrasah 1 – Physics 2, Code C: Madrasah 2 – Physics 1, Code D: Madrasah 2 – Physics 2, P: Pre-test, O: Post-test

Figure 3. Wright maps stacking analysis results

Beyond these improvements, the successful implementation of the BW-ExPort model also reflects the integration of Islamic scientific ethics, emphasizing honesty in data observation and recording, responsibility in result reporting, and integrity in scientific collaboration. The scientific process embedded in the model, from problem identification, data collection, experimental reporting, to discussion and evaluation, encouraged not only logical reasoning but also the practice of ethical integrity.

These values align with Islamic principles of scientific ethics, as outlined by Yumesri et al. (2024), which emphasize sincerity (*ikhlas*), honest methodology, and socially and spiritually beneficial goals. In the context of science education, these ethics form the character foundation guiding students not only in seeking scientific truth but also in fulfilling their responsibilities as knowledge seekers.

The racking analysis was conducted to evaluate changes in item difficulty representing critical thinking indicators after implementing the BW-ExPort model. This analysis aimed to identify how indicators such as interpretation, explanation, analysis, evaluation, and inference shifted in difficulty due to instructional intervention.

The visualization shows that several items initially considered difficult in the pre-test stage shifted to lower logit levels in the post-test. For instance, items P10 and P20, which were initially in the high logit range (+5 to +8), moved to moderate or even low levels after instruction. Interpretation and explanation indicators exhibited the most notable reduction in difficulty, suggesting that students became more adept at articulating experimental data and systematically explaining scientific phenomena.

Conversely, items associated with evaluation and inference indicators remained in the higher logit range, indicating that students still required more time and scaffolding to develop advanced critical thinking skills. These findings reinforce those from the stacking analysis, suggesting that the BW-ExPort model is particularly effective in strengthening lower- to mid-level critical thinking skills. The following Wright Map illustrates the comparative positions of critical items between the pre-test and post-test:

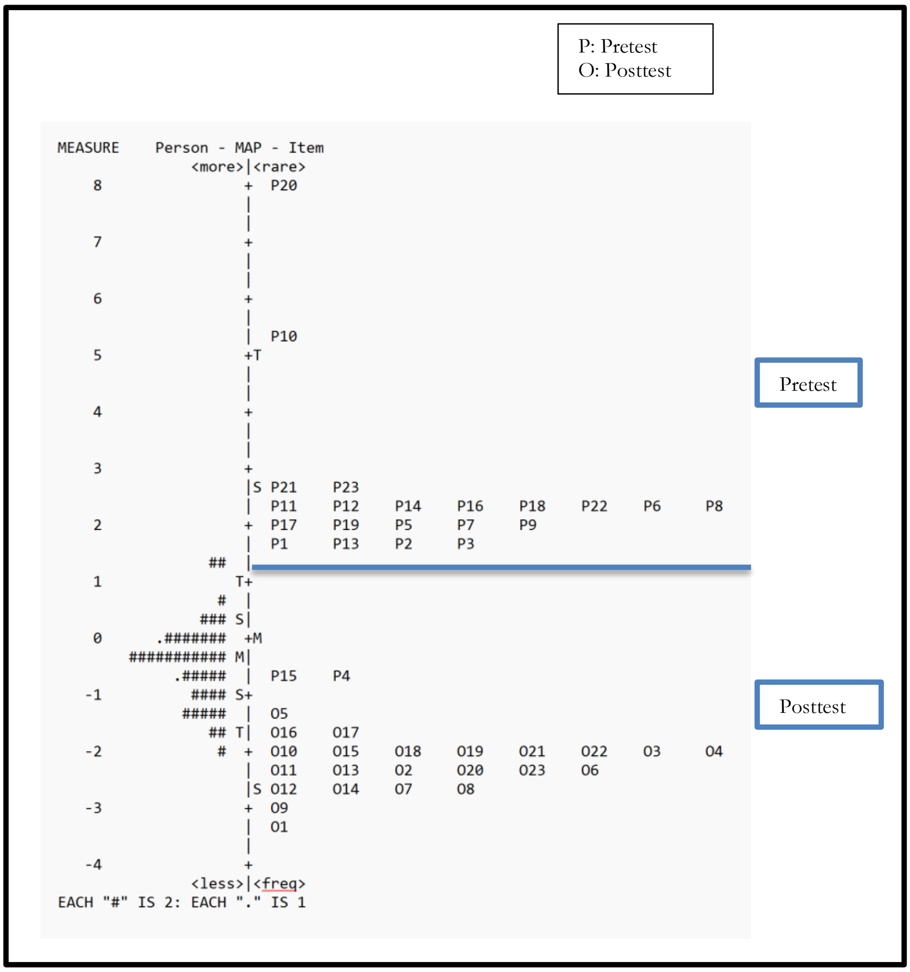


Figure 4. Wright maps the racking analysis results

From a values-based educational perspective, these developments also show that students experienced not only cognitive growth but also guidance toward responsible scientific skills. The reduction in item difficulty resulted not only from cognitive training but also from the structured thinking instilled through digital scientific reporting via Canva Docs, as well as the discussion and reflection activities that foster an Islamic scientific ethical culture. The ability to interpret data and formulate logical explanations reflects trustworthiness, honesty, and responsibility-core values in Islamic intellectual tradition. Overall, the racking analysis indicates that the BW-ExPort model successfully reduced the difficulty levels for most indicators, particularly those related to conceptual understanding and scientific reporting. Nonetheless, continued reinforcement is needed for higher-order critical thinking indicators, especially in the domains of evaluation and inference.

These findings align with previous studies, which have shown that scientific writing activities in science education significantly contribute to conceptual understanding and higher-order thinking (Gunel et al., 2007; Hike & Hughes-Phelan, 2020; Jashari & Fojkar, 2019; Keys et al., 1999). Argument-based approaches, such as ADI, have also proven effective in enhancing scientific reasoning (Admoko et al., 2021; Amelia et al., 2020; Safitri et al., 2020; Sampson et al., 2011). By integrating the core strengths of SWH and ADI, the BW-ExPort model provides a pedagogical framework that is both concise and cognitively profound.

From a technological perspective, the integration of Canva Docs in BW-ExPort provides a unique advantage in increasing student engagement. Canva Docs enables real-time collaboration, rapid feedback exchange, and continuous revision. These collaborative features foster student ownership of the learning process and enhance peer interaction, aligning with Vygotsky's sociocultural theory, which emphasizes the importance of cultural tools in mediating learning. Its visually interactive interface aligns with the characteristics of today's digital learners. The ability to embed diagrams, graphs, and visual annotations not only enhances the appeal of the reports but also supports more profound and meaningful cognitive processing.

Pedagogically and socially, the BW-ExPort model fosters active interaction among teachers and students, as well as among students. The elaboration phase, in particular, becomes a platform for meaningful discussion and reflective thinking (Roberts et al., 2014; Wu et al., 2023). This model also supports the use of virtual laboratories to address limitations in physical infrastructure (Hofstein & Mamlok-Naaman, 2007).

Thus, BW-ExPort is not only a solution to time constraints and scientific literacy gaps but also a comprehensive instructional model that integrates scientific knowledge, technology, and Islamic values. For future development, further cross-contextual studies, the integration of advanced digital tools, and the exploration of additional competencies, such as creativity and collaboration, are recommended (Chin & Osborne, 2010).

CONCLUSION

This study has successfully developed the BW-ExPort learning model (Based–Writing–Experimental Report), which has been proven valid, practical, and effective in enhancing critical thinking skills among MA students on the topic of electricity in physics education. The model synthesizes the principles of Science Writing Heuristic (SWH) and Argument-Driven Inquiry (ADI), while integrating hands-on experiments, digital scientific report writing through Canva Docs, and structured reflective discussions to foster students' scientific reasoning. Expert validation confirmed that the model and its instructional components exhibit strong content and construct validity, supported by consistent reliability. The practical implementation of the model in two partner madrasahs demonstrated high feasibility, as indicated by the smooth execution of its learning syntax and the positive responses from both teachers and students. In terms of effectiveness, Rasch model analysis, using stacking and racking, revealed significant improvements in students' critical thinking abilities. The logit shifts from low to medium and high categories indicated progress in students' interpretation, explanation, and analytical skills. However, higher-order indicators such as evaluation and inference still require additional scaffolding and intensive teacher guidance. Beyond cognitive outcomes, this model promotes Islamic scientific ethics, including trustworthiness (*amanah*), honesty, and accountability in the process of scientific reporting. Thus, BW-ExPort not only strengthens 21st-century competencies but also cultivates scientific character in alignment with Islamic educational values. In conclusion, BW-ExPort provides an adaptive pedagogical alternative that addresses the challenges of physics education in the digital era. It is particularly well-suited for broader implementation in madrasahs and secondary schools that prioritize scientific literacy, critical thinking skills, and Islamic values.

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