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Profile of High School Students' Numeration Literacy Abilities Using Formative Websites on Straight Movement Materials

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Abstract – *This study addresses the continuing urgency to strengthen students' numeracy literacy, a core competence needed to interpret quantitative information and solve contextual problems in physics learning. It aims to profile high school students' numeracy literacy abilities on static material using a technology-supported formative assessment. A quantitative descriptive design was employed with 51 students from a senior high school in Surakarta selected through purposive sampling. Data were collected using a 30-item context-based numeracy literacy test administered via the Formative website and scored dichotomously, then analyzed using Rasch modelling with the QUEST program to obtain person-ability estimates and classify students into high, medium, and low categories. The results show that students' numeracy literacy levels were distributed across the Medium (51%) and High (49%) categories, with no students in the Low category. Indicator-level findings reveal the strongest performance in interpreting quantitative information and representations (Indicator 1). At the same time, higher-level attainment was limited in applying numerical operations and formulas (Indicator 2), where no responses reached the Advanced category, and contextual reasoning (Indicator 3), which was dominated by Basic–Proficient levels. The novelty of this study lies in providing a Rasch-based diagnostic profile of numeracy literacy, specifically in straight motion, using an online formative assessment platform, yielding detailed evidence across indicators that can inform targeted instructional support. In conclusion, students demonstrated adequate numeracy literacy in straight motion overall, but improvements are needed in procedural fluency and contextual reasoning. This study contributes to physics education by demonstrating an efficient approach to diagnosing numeracy-related learning needs and supporting data-driven planning for physics instruction and assessment.*

Keywords: *kinematics; numeracy literacy; online formative assessment; physics education; Rasch model*

I. INTRODUCTION

Education is widely recognized as a foundational driver of social and economic development because it shapes the quality of human resources and, consequently, a country's long-term competitiveness (Irawan et al., 2023). For school systems, this emphasis translates into the need to strengthen not only access and participation but also the quality of learning outcomes that meet contemporary societal demands. In Indonesia, policy direction plays a central role in structuring such improvement efforts, including initiatives to align curriculum, pedagogy, and assessment with the competencies needed in modern life. One policy instrument that reflects this orientation is Merdeka Belajar Kampus Merdeka (MBKM), which is positioned to support the development of core competencies, including literacy and numeracy, as foundations for lifelong learning and workforce readiness (Pamungkas et al., 2023). Within this context, strengthening numeracy is not treated as an isolated mathematics agenda, but as part of a broader strategy to improve learning quality, student agency, and evidence-informed teaching practices (Salmia & Malik, 2025). At the classroom level, this policy orientation implies that schools require credible information about students' foundational competencies so that instructional decisions and learning supports can be planned based on evidence rather than assumptions. Profiling students' numeracy literacy is therefore relevant not only for research purposes but also for improving the alignment between curriculum intentions, classroom practice, and student outcomes.

The prioritization of numeracy aligns with broader 21st-century learning frameworks that emphasize critical thinking, communication, collaboration, and creativity as competencies required for success in a globally connected society. Contemporary scholarship further emphasizes that these competencies are intertwined with digital literacy, problem-solving, and effective communication, particularly as learners increasingly engage with information in digital environments (Chyan et al., 2023). Because future social and economic conditions are uncertain and rapidly changing, education is expected to cultivate transferable reasoning capacities rather than narrow procedural skills (Mansyur et al., 2024). Numeracy literacy is central to this agenda because it supports the practical use of quantitative information in everyday contexts (Han et al., 2017). Numeracy is increasingly framed as a critical competence for interpreting quantitative information and making informed decisions in contemporary society, extending beyond routine mathematical procedures to contextual reasoning and critical judgment (Geiger & Schmid, 2024). Importantly, numeracy literacy is grounded in contexts appropriate to geographical and socio-cultural conditions and aligned with the scope of mathematics used in real situations (Nursyamsudin & Jaelani, 2021). In this sense, numeracy differs from mathematical competence: possessing mathematical knowledge does not automatically imply the ability to apply it to unstructured problems, problems with multiple valid solutions, or tasks influenced by non-mathematical factors (Tenny et al., 2021). This conceptual distinction suggests that strengthening numeracy requires deliberate opportunities for students to interpret contexts, select representations, justify reasoning, and connect procedures to meaning.

Despite its recognized importance, evidence from large-scale assessments indicates that numeracy-related outcomes remain a persistent challenge. OECD (2019) reported that Indonesian students ranked 74th out of 79 participating countries in PISA 2018, with scores of 371 in reading, 379 in mathematics, and 396 in science. Such results suggest that many students may still face difficulty in interpreting information, modeling situations, and making justified decisions based on quantitative evidence. At the task-performance level, students often encounter obstacles in understanding problem statements, constructing appropriate mathematical models, executing mathematical procedures, and drawing conclusions consistent with the solution process (Simamora & Akhiruddin, 2022). These recurring difficulties are consequential because they constrain students' ability to learn from data, to evaluate claims critically, and to connect formal knowledge with authentic problems. Accordingly, strengthening numeracy literacy within the Merdeka Curriculum can be understood as a strategic response to assessment evidence, aimed at improving students' critical thinking, analytical reasoning, and problem-solving capacity in ways that are relevant across subjects and daily life.

In science education, physics provides a particularly relevant context for examining numeracy literacy, as many physics concepts require learners to interpret quantities, represent relationships, and justify solutions using evidence. Straight motion (rectilinear motion), as a foundational topic in physics, is frequently associated with misconceptions and fragmented understanding. One contributing factor is that students may rely on memorizing formulas presented in textbooks or by teachers without examining the conceptual basis and conditions of use of those formulas (Triastutik et al., 2021). In practice, difficulties can arise at multiple stages of problem-solving, including understanding the situation described, selecting a suitable relationship among variables, and manipulating equations to meet the task's requirements. Students may also experience barriers in performing numerical calculations accurately and in interpreting graphs and other visual representations of motion. These difficulties indicate a need for learning and assessment strategies that support conceptual understanding while also training analytical and practical abilities required for quantitative reasoning in physics (Zainuddin et al., 2021). If these difficulties are not identified early and addressed systematically, they may persist and reduce students' readiness for subsequent physics topics that build on kinematics and mathematical modeling.

A general response to these challenges is to strengthen numeracy literacy through assessment practices that provide diagnostic information about students' reasoning and their use of quantitative representations. In the context of the Merdeka Curriculum, which emphasizes the development of critical thinking and problem-solving, assessment instruments that explicitly target numeracy literacy can help translate curriculum expectations into observable student performance. From an educational measurement perspective, such instruments should be designed to capture not only procedural accuracy but also understanding of mathematical concepts within context, the ability to solve numerical problems systematically, and competence in analyzing and interpreting data. When aligned with physics learning, assessment tasks can be constructed to require students to connect physical meaning with mathematical representation, for example, by interpreting motion situations, reasoning about variable relationships, or reading and constructing graphs. Consequently, a well-designed diagnostic assessment can support educators and school leaders in identifying patterns of strengths and weaknesses, selecting appropriate instructional responses, and monitoring progress over time. This approach positions assessment as part of learning support rather than a terminal judgment, thereby improving the educational value of measurement activities.

In recent years, digital assessment has been proposed as a practical pathway for implementing diagnostic and formative evaluations more efficiently. However, in many school contexts, assessment is still predominantly conducted through paper-based tests and manual scoring. Such practices can reduce student engagement, increase opportunities for academic dishonesty, and impose substantial time demands on teachers (Primaniarta & Mulyani, 2020). Conventional written assessments are also frequently described as complicated, time-consuming, and less efficient than technology-supported alternatives (Salsabila et al., 2022). Advances in information system technology, including integrated online data storage and flexible access, enable educators to conduct assessment beyond classroom constraints and to provide faster feedback to students (Schildkamp et al., 2020; Atasoy & Kaya, 2022; Staberg et al., 2023; Sullivan et al., 2021; Maier et al.,2016). In this context, educators are increasingly expected to keep pace with technological developments and to implement online assessment as a complement to offline methods (Hariono et al., 2021). Online assessment media can streamline item administration and scoring and encourage more innovative evaluation practices that leverage available web applications (Husna et al., 2023). Digital platforms also make it feasible to present items in interactive formats, to incorporate visual representations such as tables or graphs more naturally, and to provide immediate results for reflection by both teachers and students. When combined with appropriate analytic approaches, online assessment can move beyond efficiency toward more informative measurement that supports formative decision making. Nevertheless, important research gaps remain: studies that profile students' numeracy literacy specifically within physics topics, particularly straight motion using context-based items, are still limited, and many online assessments continue to rely mainly on classical test approaches rather than analytic methods that can produce interpretable ability estimates for diagnostic use. Online formative assessment can strengthen learning by enabling timely feedback and richer teacher–student interactions, particularly in science/physics learning environments (Kim & Song, 2023).

Responding to these needs and gaps, this study aims to profile high school students' numeracy literacy in a straight motion by administering context-based physics items through a formative website platform and analyzing student responses to generate an ability profile. The study is designed as an initial diagnostic effort to describe students' numeracy literacy levels in a physics context, rather than to evaluate the effectiveness of a particular instructional intervention. By using an online platform, the study also illustrates the practical utility of technology-supported assessment for efficiently delivering numeracy-oriented items. The resulting profile is expected to support educators, including prospective physics teachers, in identifying students' strengths and weaknesses and in designing more targeted learning support aligned with the goals of the Merdeka Curriculum and the demands of 21st-century learning.

II. METHODS

This study used a quantitative descriptive design to map and describe senior high school students' initial numeracy literacy in the topic of straight motion. The aim was to generate an ability profile from assessment data rather than to evaluate an instructional intervention. The participants were 51 students from one senior high school in Surakarta, Indonesia. Students were recruited using purposive sampling, considering school accessibility and the alignment of student characteristics with the study objective (i.e., profiling students' baseline numeracy literacy in physics learning)

Data were collected using a 30-item numeracy literacy test developed specifically for the straight-motion context. Item construction followed contextual numeracy literacy indicators: (1) interpreting quantitative information in real-world contexts; (2) applying mathematical concepts and formulas in physics situations; (3) analyzing numerical data presented in tables, graphs, and diagrams; and (4) reasoning and drawing conclusions based on numerical information related to motion phenomena.

To ensure balanced measurement across indicators, the distribution of items was arranged to represent multiple aspects of numeracy literacy. The instrument comprised multiple-choice items with contextual problem scenarios, incorporating representations commonly used in physics, such as motion graphs, tables of displacement, time, or velocity time data, short contextual texts, and symbolic equations. Item format can influence observed performance and measurement characteristics. Therefore, the use of multiple-choice items should be interpreted with attention to potential format effects (Marcq et al., 2024). These formats were selected to reflect authentic physics problem situations that require numeracy reasoning rather than routine calculation. The cognitive demand of the items ranged from understanding and application to analysis and reasoning, aligned with numeracy literacy characteristics. Each item was scored dichotomously: 1 point for a correct answer and 0 for an incorrect answer.

The assessment was administered online via the Formative platform to standardize delivery and automatically record student responses. The overall workflow of the study and the assessment procedure is illustrated in Figure 1, including administration, data screening, and analysis. Before analysis, response data were screened for completeness and validity; incomplete submissions and invalid response patterns were excluded from the dataset.

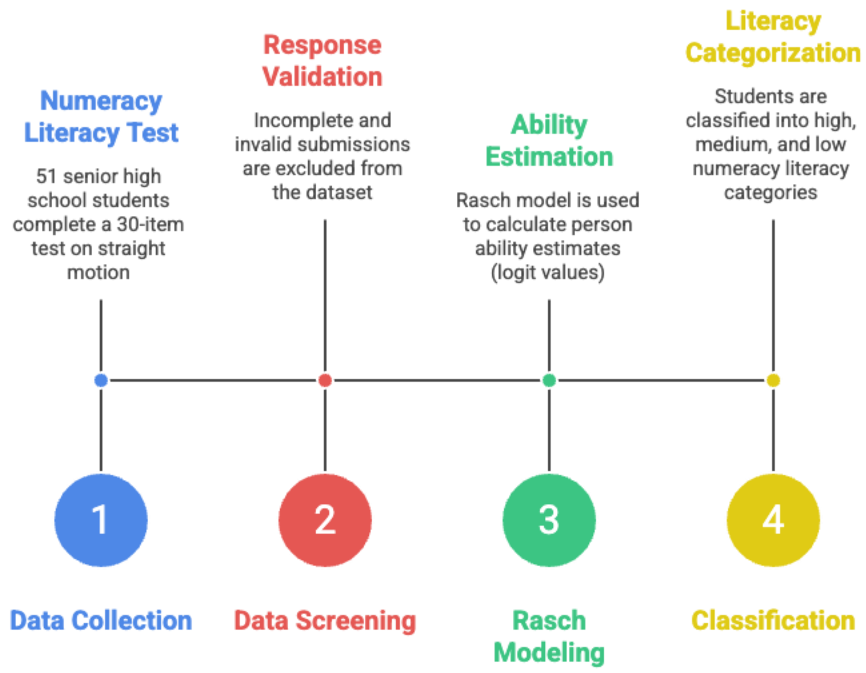

Figure 1. Research workflow and assessment procedure

Cleaned response data were analyzed using the Rasch Model with the QUEST program to obtain person ability estimates (logit values) for each student. Rasch modeling provides interpretable person-ability estimates on a common logit scale and supports diagnostic profiling of learners' competencies (Avinç & Doğan, 2024; Planinić et al., 2019). Similar Rasch-based procedures have been used in science education research for instrument evaluation and competency profiling (Zoechling et al., 2022; Boone, 2016). These estimates represent students' numeracy literacy levels based on their overall response patterns across the test items, rather than relying solely on raw scores. Based on the obtained logit estimates, students' numeracy literacy abilities were classified into high, medium, and low categories following the criteria proposed by Hanna and Retnawati (2022), as presented in Table 1.

Table 1. Criteria for categorizing students' numeracy literacy ability based on Rasch person estimates

No	Estimated value	Criteria
1	>1.00	High ability
2	-1.00 – 1.00	Medium ability
3	< -1.00	Low ability

III. RESULTS

Students' numeracy literacy in the straight-motion topic was classified into High, Medium, and Low categories using Rasch person-ability estimates, with the cut-off criteria referring to Table 1. The classification results indicate that students' abilities were concentrated in the two upper categories, reflecting a generally adequate baseline numeracy literacy profile within the sampled cohort. Importantly, no students were classified in the Low category, suggesting that the minimum expected numeracy performance—based on the applied Rasch estimate thresholds—was achieved by all participants. This overall categorization provides a cohort-level description of numeracy literacy readiness before any instructional treatment or intervention.

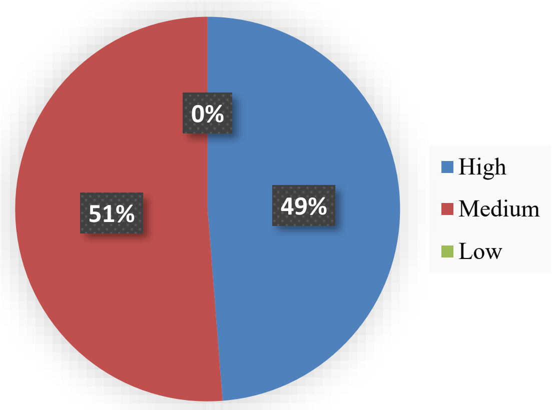

Figure 2. Distribution of students' numeracy literacy categories (high, medium, low) in straight motion based on Rasch person-ability classification

The distribution of students across the overall categories is communicated visually in Figure 2, which shows a near-balanced pattern between the medium and high groups. Specifically, the medium category represents a slightly larger proportion of the cohort (51%) than the High category (49%), indicating that most students demonstrated competence that met the criteria for at least medium numeracy literacy, while nearly half reached the high category. The absence of the Low category in the distribution is notable because it suggests that none of the students exhibited response patterns corresponding to low person-ability estimates under the Rasch model. In practical terms, the cohort profile is characterized more by differentiation between moderate versus higher numeracy literacy rather than by a broad spread that includes low-performing students.

To complement the cohort-level classification, students' performance was further examined at the indicator level to describe how response quality varied across different numeracy literacy demands. The indicator-level distributions are summarized in Table 3, which reports student responses across four proficiency levels—Below Basic, Basic, Proficient, and Advanced—for each indicator. This table therefore provides a more granular view of students' numeracy literacy profile by distinguishing between minimal performance, foundational competence, adequate mastery, and higher-order performance within specific indicator domains. Across the three indicators, the dominant response level is consistently Proficient, indicating that students most frequently demonstrated adequate numeracy literacy rather than only basic competence or sustained advanced performance.

Table 3. Distribution of numeracy literacy proficiency levels (below basic, basic, proficient, advanced) across indicators

No	**Numeracy literacy ability criteria**	**Number of student responses**		
		Indicator 1	**Indicator 2**	**Indicator 3**
		Amount	Amount	Amount
		Percentage	Percentage	Percentage
1	Below basic	1	11	9
		1%	9%	7%
2	Basic	13	46	48
		11%	38%	40%
3	Proficient	53	64	56
		44%	53%	46%
4	Advanced	54	0	8
		45%	0%	7%

For Indicator 1 (9 items), Table 3 shows that students' responses were heavily concentrated in the upper proficiency levels, with Proficient (44%) and Advanced (45%) accounting for the vast majority of responses. In contrast, the proportions in Basic (11%) and Below Basic (1%) were relatively small, indicating that only a limited fraction of responses fell within the lower proficiency bands for this indicator. This pattern suggests that, for the numeracy demands represented by Indicator 1, many students demonstrated not only adequate performance but also higher-level proficiency. The distribution also indicates a strong separation from low performance on this indicator, as reflected by the minimal presence of Below Basic responses.

For Indicator 2 (6 items), the distribution in Table 3 shifts toward mid-level proficiency, with responses dominated by Proficient (53%) and Basic (38%). A smaller proportion of responses fell into the Below Basic category (9%), and, notably, Advanced responses were absent (0%). This configuration indicates that, while most students were able to reach at least a proficient level on Indicator 2 items, performance rarely extended into the highest proficiency band. The absence of Advanced responses suggests that the numeracy processes required by Indicator 2 constrained students' ability to consistently demonstrate high-level mastery. Compared with Indicator 1, Indicator 2 also shows a greater share of lower-band responses (Below Basic and Basic combined), indicating a larger proportion of responses that did not reach the Proficient or Advanced levels.

For Indicator 3 (7 items), Table 3 shows a broader spread across proficiency levels, though the largest proportions remain in the mid-to-upper bands. Specifically, Proficient (46%) constitutes the largest share of responses, followed by Basic (40%), while Below Basic (7%) and Advanced (7%) appear in smaller but non-negligible proportions. This pattern indicates variability in students' performance for Indicator 3, with a substantial segment of responses remaining at the Basic level alongside a comparable concentration at Proficient. At the same time, the presence of Advanced responses—although limited—suggests that some students were able to reach higher proficiency on this indicator, but such performance was not widespread across the cohort. Compared to Indicator 1, the distribution for Indicator 3 is less concentrated at the top end, and compared to Indicator 2, it includes at least a small Advanced component.

When the indicator-level results are viewed collectively, Table 3 shows that students' strongest performance profile occurs in Indicator 1, which has the highest combined share of Proficient and Advanced responses. In contrast, Indicator 2 is characterized by the absence of Advanced responses and a greater reliance on the Basic band, indicating that high-level proficiency was least evident for this indicator. Indicator 3 occupies an intermediate position, with Proficient responses as the largest proportion but accompanied by a substantial Basic component and smaller shares at the extremes. Overall, the combined results indicate that, although the cohort-level classification (Figure 2) suggests generally moderate-to-high numeracy literacy, the indicator-level distributions reveal meaningful differences in how consistently students achieved high proficiency across distinct numeracy literacy demands.

IV. DISCUSSION

The findings indicate that students' numeracy literacy in straight motion is distributed exclusively across the Medium (51%) and High (49%) categories, with no students classified as Low. From a measurement perspective, this pattern suggests that the cohort possesses a baseline capability to engage with numeracy-oriented physics tasks in a relatively stable manner. Nevertheless, the near-even split between Medium and High also indicates that a substantial proportion of students has not yet demonstrated consistently high numeracy performance across the full range of items. This distinction is important because numeracy literacy is not merely reflected by correct computation; it is characterized by the ability to interpret contextual information, select appropriate representations, and justify quantitative conclusions (Nursyamsudin & Jaelani, 2021; Tenny et al., 2021). Therefore, the overall distribution can be interpreted as evidence that students generally possess adequate numeracy literacy for straight motion. Still, that consolidation toward higher-level competence remains necessary for many learners.

The indicator-level profile provides a clearer explanation of why Medium-level performance remains dominant. Indicator 1 shows a strong concentration in the Proficient (44%) and Advanced (45%) categories, with minimal proportions in the Basic and Below Basic categories. This suggests that students are capable of interpreting quantitative representations of straight motion, such as reading information from graphs and tables and identifying relationships among variables. Such performance is consistent with the expectation that representational interpretation is frequently practiced in physics learning through exposure to graphs and tabulated data. However, numeracy literacy requires that this representational competence be integrated with deeper reasoning and decision making in context (Han et al., 2017). Thus, high performance on Indicator 1 should not be interpreted as comprehensive numeracy mastery, but rather as strength in one critical component of the numeracy construct.

In contrast, Indicator 2 reveals a different pattern, with responses dominated by Proficient (53%) and Basic (38%), and no Advanced (0%) and Below Basic (9%) performance. This absence of Advanced responses is particularly meaningful in the context of straight motion, as this topic demands a flexible, accurate application of formulas across varied conditions. The results suggest that although many students can execute standard procedures, a considerable portion still struggles to achieve higher-level fluency that involves selecting efficient strategies, maintaining accuracy across multi-step computations, and evaluating whether a numerical result is physically reasonable. This finding aligns with concerns that students may approach physics problems by memorizing formulas without developing a strong conceptual understanding of when and how to apply them (Triastutik et al., 2021). When procedural application is not grounded in conceptual understanding, students may obtain correct answers in routine items but fail to demonstrate advanced performance when tasks require adaptation, precision, or interpretation of constraints.

Indicator 3 further clarifies the challenge in contextual reasoning. The distribution, concentrated in Basic (40%) and Proficient (46%), with smaller proportions in Below Basic (7%) and Advanced (7%), indicates variability in students' ability to integrate information and draw justified conclusions. This pattern suggests that contextual numeracy tasks that require learners to interpret the problem situation, identify relevant variables, connect quantitative information to physical meaning, and produce defensible conclusions are more demanding than tasks focused primarily on reading representations. Such difficulty is consistent with prior evidence that students often struggle to understand problems, build models, and draw appropriate conclusions (Zavala et al., 2017; Simamora & Akhiruddin, 2022). In physics, these challenges may be amplified because students must coordinate conceptual understanding of motion with mathematical representation and numerical reasoning (Zainuddin et al., 2021). The presence of a small Advanced group indicates that higher-level reasoning is achievable within the cohort. Still, the large Basic proportion shows that many students may rely on partial reasoning or incomplete integration of information.

Taken together, the results highlight a gradient in numeracy literacy performance: students demonstrate the strongest outcomes in interpreting representations (Indicator 1). At the same time, limitations are more evident in procedural–computational fluency (Indicator 2) and in contextual reasoning and conclusion-making (Indicator 3). This pattern supports the argument that numeracy literacy should be conceptualized as an integrated competence rather than a single skill. Even when students can read graphs and tables effectively, they may still experience difficulty when they must transform that information into a solution strategy, execute calculations reliably, and interpret outcomes in context. This interpretation is consistent with the view that numeracy literacy is distinct from mathematical competence and requires contextual application (Nursyamsudin & Jaelani, 2021; Tenny et al., 2021). It also reflects broader educational concerns that strengthening numeracy is central to developing critical thinking and problem-solving capacity within 21st-century learning (Chyan et al., 2023; Mansyur et al., 2024).

From an instructional and assessment perspective, these findings underscore the importance of using technology-supported formative assessment to diagnose students' competency profiles efficiently. Traditional paper-based assessment can be time-consuming, reduce engagement, and create opportunities for cheating (Primaniarta & Mulyani, 2020), while conventional written assessments may also be operationally complex and less efficient (Salsabila et al., 2022). Online assessment, supported by advances in information systems, provides flexibility and accessibility and can facilitate more innovative evaluation practices (Hariono et al., 2021; Husna et al., 2023). In this study, the use of a formative website enabled efficient administration and systematic data capture, supporting the production of a detailed indicator-level profile. Such profiling can help teachers focus remediation and enrichment efforts: strengthening advanced-level performance in procedural application and contextual reasoning may require learning experiences that explicitly connect formulas to conceptual meaning, incorporate multi-step modeling tasks, and provide structured opportunities for students to justify solutions and evaluate reasonableness in physical contexts. In this way, the assessment approach used in the study aligns with the broader policy and curriculum direction that emphasizes foundational competencies and evidence-informed learning support (Irawan et al., 2023; Pamungkas et al., 2023).

Finally, the results contribute to the literature by providing a focused profile of numeracy literacy within a specific physics topic, straight motion using an online assessment platform and Rasch-based analysis for categorization. This complements previous work on numeracy literacy variability in physics contexts (Damanik & Sani, 2025) by offering detailed distributions across indicators and levels. While the cohort did not include Low-category students, the indicator results show that significant improvement is still needed to move more students from moderate competence toward consistently high and advanced numeracy literacy, especially in tasks requiring flexible computation and contextual reasoning.

V. CONCLUSION AND SUGGESTION

This study profiled high school students' numeracy literacy in a straight motion using an online assessment administered through a formative website and analyzed with Rasch modeling. The results indicate that students' numeracy literacy levels were distributed across medium (51%) and high (49%), with no students classified in the low category. At the indicator level, students demonstrated the strongest performance in interpreting quantitative information and representations (indicator 1), as reflected by the high proportions in the proficient and advanced categories. In contrast, performance in applying numerical operations and formulas (indicator 2) and contextual reasoning and conclusion-making (indicator 3) showed comparatively lower upper-level attainment, including the absence of advanced responses for indicator 2 and the dominance of basic–proficient levels for indicator 3. Overall, these findings suggest that students' representational interpretation skills in straight motion are relatively strong, while procedural fluency and contextual reasoning remain key areas for improvement.

Several limitations should be acknowledged. First, the study involved a single school and a small sample size (51 students), limiting the generalizability of the findings to broader student populations. Second, the study used a 30-item multiple-choice instrument, which may not fully capture students' reasoning processes compared with constructed-response tasks or interviews. Third, the study focused on one physics topic (straight motion); therefore, the observed profile may differ across other physics domains that involve different representational and mathematical demands. Future research should involve larger and more diverse samples across schools and regions, incorporate mixed assessment formats (e.g., open-ended items and qualitative probing of reasoning), and compare numeracy literacy profiles across multiple physics topics. Despite these limitations, this study contributes to physics education by providing a Rasch-based diagnostic profile of numeracy literacy in a core kinematics topic and by demonstrating the practical utility of technology-supported formative assessment for efficiently capturing student performance patterns. The indicator-level results provide actionable evidence for educators to design targeted learning support, particularly to strengthen students' formula-based quantitative reasoning and contextual decision-making in physics problem-solving.

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