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Analysis of student items and abilities on the scientific literacy and biology creativity instruments

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Abstract

Indonesia ranked 68th out of 81 nations in PISA 2022 science (mean score 398 vs. OECD average 485), underscoring urgent deficits in scientific literacy and creativity among Indonesian students. This study analyzed these two competencies among 108 10th-grade students across three classes (X E7, X E8, X E10) on ecosystem topics, using a 36-item five-point Likert-scale questionnaire 18 scientific literacy items (science content, process, context, and attitudes) and 18 creativity items (fluency, flexibility, originality, elaboration, curiosity, and risk-taking) validated through Rasch Partial Credit Model analysis. Results revealed very high internal consistency (scientific literacy α=0.959; creativity α=0.947); however, all 36 items exhibited systematic overfit infit MNSQ values (range: 0.20–0.61; mean: 0.372 and 0.381 respectively), indicating inter-item redundancy and insufficient construct breadth. Despite this limitation, both instruments demonstrated strong unidimensionality and remained well-targeted for this population. A very strong positive correlation was found between scientific literacy and creativity (r=0.903), with Class X E10 achieving the highest mean ability for both constructs. These findings provide pedagogical recommendations to strengthen science process and originality dimensions in biology learning, while highlighting the need to diversify item content and difficulty range in future instrument development.

Abstrak. *Indonesia berada di peringkat ke-68 dari 81 negara dalam sains PISA 2022 (skor rata-rata 398 vs rata-rata OECD 485), yang menunjukkan adanya defisit yang mendesak dalam literasi sains dan kreativitas di kalangan pelajar Indonesia. Studi ini menganalisis dua kompetensi di antara 108 siswa kelas 10 di tiga kelas (X E7, X E8, X E10) pada topik Ekosistem, menggunakan 36 item kuesioner skala Likert lima poin 18 item literasi sains (konten sains, proses, konteks, dan sikap) dan 18 item kreativitas (kefasihan, fleksibilitas, orisinalitas, elaborasi, rasa ingin tahu, dan pengambilan risiko) divalidasi melalui analisis Model Kredit Parsial Rasch. Hasil menunjukkan konsistensi internal yang sangat tinggi (literasi sains α=0,959; kreativitas α=0,947); namun, semua 36 item menunjukkan nilai MNSQ overfit infit yang sistematis (kisaran: 0,20–0,61; rata-rata: masing-masing 0,372 dan 0,381), yang menunjukkan redundansi antar-item dan luas konstruk yang tidak memadai. Meskipun terdapat keterbatasan, kedua instrumen menunjukkan unidimensionalitas yang kuat dan tetap tepat sasaran untuk populasi ini. Terdapat korelasi positif yang sangat kuat antara literasi sains dan kreativitas (r=0,903), dengan Kelas X E10 mencapai rata-rata kemampuan tertinggi untuk kedua konstruk tersebut. Temuan ini memberikan rekomendasi pedagogi untuk memperkuat dimensi proses sains dan orisinalitas dalam pembelajaran biologi, sekaligus menyoroti kebutuhan untuk mendiversifikasi konten item dan rentang kesulitan dalam pengembangan instrumen di masa depan.Abstrak berisi ringkasan isi artikel secara keseluruhan. Abstrak bermaksud menyampaikan poin-poin paling penting dari artikel jurnal.*

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A. Introduction

Scientific literacy and creativity are two fundamental 21st-century competencies that have become central demands in global educational systems. The Programme for International Student Assessment (PISA) defines scientific literacy as the ability of individuals to engage with science-related issues, understand scientific concepts, and explain natural phenomena using evidence (OECD, 2023). This definition affirms that scientific literacy is not merely declarative knowledge; it encompasses procedural and contextual dimensions requiring higher-order thinking. Meanwhile, creativity including the abilities to think fluently, flexibly, originally, and elaboratively is regarded as essential capital for navigating the complexities and uncertainties of the future (Torrance, 1966; Runco & Jaeger, 2012).

The Ecosystem topic was selected as the conceptual context for this study because its inherent complexity simultaneously demands both scientific literacy and creativity. Understanding ecosystem dynamics including energy flow across trophic levels, the regulation of carrying capacity, biogeochemical cycling, and human-induced perturbations such as eutrophication, habitat fragmentation, and biodiversity loss requires the integration of multiple science process skills: interpreting quantitative ecological data, constructing causal explanations across organizational levels, and contextualizing scientific evidence within real-world environmental problems (OECD, 2023). These demands align directly with the procedural and contextual dimensions of scientific literacy. At the same time, addressing ecological challenges creatively such as proposing nature-based conservation solutions, designing sustainable resource management strategies, or generating novel hypotheses about species interactions requires precisely the fluency, originality, and elaboration that define higher-order creativity (Torrance, 1966). Ecosystem dynamics thus provides a naturalistic and authentic context in which both constructs are organically elicited, making it an ideal domain for their joint psychometric investigation.

Internationally, concern over students' scientific literacy has intensified since PISA 2006, which first systematically measured it as a core competency. Indonesia's performance in the PISA 2022 science domain placed the country 68th out of 81 participating nations, with a mean score of 398, considerably below the OECD average of 485 (OECD, 2023). This persistent underperformance reflects a systemic issue: science education in Indonesia remains predominantly focused on the transmission of factual content rather than the cultivation of scientific reasoning and process skills. Adnan et al. (2021) confirmed this pattern in a study of junior high school students in South Sulawesi, identifying inquiry design and data interpretation as the most severely underdeveloped dimensions of scientific literacy. Similarly, Dhaniaputri and Angraini (2025) found that even biology education students at the university level face significant challenges in the science process dimension, particularly in designing methodologies and interpreting quantitative data.

The relationship between scientific literacy and creativity in science education has gained growing empirical attention. Hu et al. (2026) demonstrated that scientific literacy is a strong predictor of scientific creativity, as both competencies depend on critical thinking, evidence-based argumentation, and problem-solving. Astuti et al. (2023) found that implementing an integrated Science, Technology, Engineering, and Mathematics (STEM) approach simultaneously enhanced both scientific literacy and student creativity. Conradty et al. (2020) further showed that well-designed STEAM modules improved students' self-efficacy and motivation, two factors that indirectly support the development of creativity, Miranda et al. (2025) in European high schools observed that short-term STEM collaborative projects were effective in promoting scientific literacy, particularly its process and context dimensions.

Despite this growing body of evidence, a critical methodological gap persists. Many studies rely on classical test theory (CTT) for instrument validation, yielding sample-dependent estimates and limiting the generalizability of findings across different student groups. The Rasch Model (Rasch, 1960), as part of Item Response Theory (IRT), offers a rigorous alternative: it produces sample-free and test-free parameter estimates, enabling invariant measurement across groups (Bond & Fox, 2015). More specifically, the Partial Credit Model (PCM) developed by Masters (1982) is well-suited to polytomous data, such as Likert-scale instruments. As Sumintono and Widhiarso (2014) noted, PCM allows each response category to carry distinct step-difficulty parameters, providing a more nuanced representation of student ability and item quality than alpha reliability alone. Wright and Masters (1982) further established that the Wright Map generated by Rasch analysis provides a powerful visual tool for simultaneously examining person ability and item difficulty on a shared logit continuum a capability unavailable in CTT.

A gap analysis of existing literature reveals that, while studies on scientific literacy and creativity in Indonesian biology education are growing (Handayani et al., 2023; Komalasari et al., 2024; Putri & Vifi, 2023), investigations that simultaneously analyze both constructs using Rasch PCM as a psychometric framework at the senior high school level remain scarce. Most available studies either address A single construct in isolation or employ CTT methods that cannot adequately assess instrument quality for polytomous data. Furthermore, few studies have investigated inter-class ability disparities within the same school using invariant measurement, even

though such disparities have significant implications for instructional equity. This study, therefore, addresses a substantive methodological and empirical gap.

This study aims to: (1) analyze the item quality of scientific literacy and creativity instruments using PCM analysis; (2) describe the student ability profile across three study groups; (3) compare student ability across classes; and (4) examine the correlation between scientific literacy and creativity as a basis for evidence-based pedagogical recommendations. The novelty of this study lies in its simultaneous, Rasch-based psychometric analysis of both constructs using a jointly validated instrument administered to a multi-class sample, enabling cross-group comparisons with invariant ability estimates. Findings are intended to provide a robust empirical foundation for designing innovative, context-rich biology learning that builds 21st-century competencies.

B. Material and method

This research adopted a quantitative approach with a descriptive-analytic survey design. The population comprised all 10th-grade students of SMA Negeri 2 Kudus, Central Java, Indonesia. A total of 108 students across three purposively selected study groups participated: X E7 (n=36), X E8 (n=36), and X E10 (n=36). Data were collected in April 2026 via A Google Form.

Instruments both instruments were developed through a structural three-stage validation process prior to administration. First, content validity was established through an expert panel review conducted by two subject-matter specialists in biology education and one specialist in educational measurement, who independently evaluated each item for its relevance to the target constructs, linguistic clarity, and alignment with the respective theoretical frameworks, the PISA 2022 Science Framework (OECD, 2023) for scientific literacy and the Guilford-Torrance divergent thinking model (Guilford, 1967; Torrance, 1966) for creativity. Items receiving a Content Validity Ratio (CVR) below the minimum threshold (Lawshe, 1975) were revised or eliminated. Second, face validity and initial readability were confirmed through a small-group pilot administration involving nine students drawn from non-participant classes, ensuring that item wording was interpretable and unambiguous. Third, contruct validity and psychometric quality were evaluated using the Rasch Partial Credit Model (PCM), which assessed item fit statistics (infit MNSQ), item difficulty (logit), unidimensionality, person reliability, and person separation indices, the full results of which are reported in the Results section. The rasch-based analysis served simultaneously as an instrument validation framework and as the primary analytic tool for this study, consistent with current best practices for polytomous Likert-scale instruments in educational research (Bond & Fox, 2015; Sumintono & Widhiarso, 2014). Both instruments demonstrated high internal consistency prior to field implementation (Scientific Literacy $\alpha = 0.959$; Creativity $\alpha = 0.947$), exceeding the minimum standard of $\alpha \geq 0.70$ (Nunnally & Bernstein, 1994). An additional open-ended essay section grounded in an ecosystem context served as qualitative triangulation.

Analysis proceeded in two stages. First, classical descriptive statistics were computed, including mean, standard deviation, and Cronbach's alpha. Second, Rasch Model (PCM) analysis was conducted to estimate: (a) item difficulty in logits; (b) person ability in logits; (c) item fit (infit MNSQ) with a productive criterion of 0.6–1.4 (Bond & Fox, 2015; Linacree, 2002); (d) reliability and person separation index; and (e) the Wright Map for joint person–item visualization. The measured value using Formula 1.

$$V = (x / y) \times 100\% \text{ .....Formula 1}$$

Description:
V = measured value
x = score obtained
y = maximum score

Parameter estimation used the maximum likelihood approach. Pearson correlation analysis examined the relationship between scientific literacy and creativity. All computations were performed using Python 3.12 (pandas, numpy) with Chart.js for visualization.

C. Results and discussion

Descriptive statistics of total scale scores are presented in Table 1. The mean scientific literacy score (M=54.06; SD=12.43) exceeded the mean creativity score (M=51.80; SD=10.90) from the theoretical maximum of 90 points (18 items × 5). In percentage terms, mean scientific literacy reached 60.07% and creativity 57.56% of the ideal score. Class X E10 consistently obtained the highest means on both scales, while X E7 recorded the lowest.

Although the overall difference between the two mean scores is relatively small, the pattern is conceptually meaningful: students appear more comfortable expressing beliefs and understanding about science than acknowledging their own creative capacities. This finding aligns with Sulistyowati and Roshayanti (2022), who observed similarly modest creativity profiles among high school students in biology learning, and with Ilma and Sam (2024), who found that creativity scores were consistently lower than conceptual understanding scores in project-based settings. The dominance of central category (Category 3) responses in the Likert data (see Table 6) further suggests that most students hold a moderately uncertain self-assessment of both competencies.

The disparity across study groups warrants pedagogical attention. Class X E10's consistently higher performance on both constructs may reflect

differences in classroom learning climate, teacher-student interaction quality, or prior learning experiences not merely innate ability differences. Adnan et al. (2021) emphasized that inter-class disparities within the same school are frequently attributable to instructional practice variation rather than inherent student ability gaps. This interpretation is supported by the sample-free nature of Rasch estimates: the logit-based ability scores reported here are independent of item difficulty, meaning that the observed differences reflect genuine ability variation rather than an artifact of item selection.

Rasch model analysis: Item quality

The PCM analysis produced item difficulty estimates and infit MNSQ values for all 36 items. The goodness-of-fit criterion applied was the productive range of 0.6–1.4 (Bond & Fox, 2015; Linacree, 2002). Tables 2 and 3 present the Rasch statistics for scientific literacy and creativity items, respectively.

Table 1 Descriptive statistics of scientific literacy and creativity scores per class (N = 108)

Class	n	Scientific literacy (max.90)				Creativity (max.90)			
		Min	Max	M	SD	Min	Max	M	SD
X E7	36	25	81	51.42	12.91	26	75	49.22	9.68
X E8	36	28	78	52.31	11.42	27	78	50.81	11.20
X E10	36	30	84	58.44	12.04	28	81	55.36	11.11
Total	108	25	84	54.06	12.43	26	81	51.80	10.90

Note: M = mean; SD = standard deviation; max. = maximum theoretical score.

Table 2 Rasch model statistics for scientific literacy items (N = 108)

Item	Dimension	Mean	Difficulty (logit)	Infit MNSQ	Status
SL1	Content	2.926	0.074	0.27	Overfit
SL2	Content	2.824	0.176	0.56	Overfit
SL3	Content	2.972	0.028	0.38	Overfit
SL4	Content	3.092	−0.093	0.36	Overfit
SL5	Science process	2.806	0.195	0.61	Productive
SL6	Science process	2.759	0.242	0.49	Overfit
SL7	Science process	2.935	0.065	0.43	Overfit
SL8	Science process	2.981	0.019	0.36	Overfit
SL9	Science process	2.861	0.139	0.39	Overfit
SL10	Science context	3.102	−0.102	0.20	Overfit
SL11	Science context	2.944	0.056	0.33	Overfit
SL12	Science context	3.248	−0.148	0.24	Overfit
SL13	Attitude	3.222	−0.111	0.36	Overfit
SL14	Attitude	3.315	−0.317	0.30	Overfit
SL15	Attitude	3.248	−0.148	0.28	Overfit
SL16	Attitude	2.778	0.223	0.47	Overfit
SL17	Attitude	3.009	−0.009	0.36	Overfit
SL18	Attitude	3.343	−0.346	0.35	Overfit
Mean	—	—	**0.012**	**0.372**	—

Note: Logit = log-odds unit; Infit MNSQ productive range = 0.6–1.4; negative logit = easier item.

Table 3 Rasch model statistics for creativity items (N = 108)

Item	Dimension	Mean	Difficulty (logit)	Infit MNSQ	Status
CR1	Fluency	2.787	0.214	0.37	Overfit
CR2	Fluency	2.731	0.270	0.46	Overfit
CR3	Fluency	2.880	0.121	0.35	Overfit
CR4	Flexibility	2.870	0.130	0.33	Overfit
CR5	Flexibility	2.815	0.186	0.44	Overfit
CR6	Flexibility	2.907	0.093	0.28	Overfit
CR7	Originality	2.824	0.176	0.37	Overfit
CR8	Originality	2.750	0.251	0.35	Overfit
CR9	Originality	2.833	0.167	0.49	Overfit
CR10	Elaboration	2.917	0.083	0.38	Overfit
CR11	Elaboration	2.880	0.121	0.31	Overfit
CR12	Elaboration	2.898	0.102	0.37	Overfit
CR13	Curiosity	2.907	0.093	0.46	Overfit
CR14	Curiosity	2.917	0.083	0.40	Overfit
CR15	Curiosity	3.046	−0.046	0.31	Overfit
CR16	Risk Taking	2.870	0.130	0.32	Overfit
CR17	Risk Taking	2.935	0.065	0.44	Overfit
CR18	Risk Taking	3.028	−0.028	0.36	Overfit
Mean	—	—	**0.113**	**0.381**	—

Note: Logit = log-odds unit; Infit MNSQ productive range = 0.6–1.4; negative logit = easier item.

Although none of the 36 items exceeded the upper misfit boundary of 1.4 confirming the absence of erratic, construct-irrelevant response patterns a critical psychometric concern emerges from the lower end of the fit distribution. Every item on both instruments produced infit MNSQ values substantially below the lower productive boundary of 0.6, constituting systematic overfitting across both scales. For scientific literacy, infit MNSQ ranged from 0.20 (SL10) to 0.61 (SL5), with a mean of 0.372; for creativity, values ranged from 0.28 (CR6) to 0.49 (CR9), with a mean of 0.381. According to Bond and Fox (2015) and Linacree (2002), infit MNSQ values below 0.6 signal overdiscrimination: item responses are far more predictable than the Rasch model expects under genuine probabilistic measurement conditions. Three plausible explanations are consistent with the present data. First, item redundancy: items within and across dimensions may be semantically so similar that respondents produce near-identical response patterns, artificially suppressing residual variance. Second, acquiescence bias: on a five-point Likert scale in a classroom setting, social desirability may compress the response distribution toward upper categories, reducing the stochastic variation the Rasch model requires. Third, restricted construct coverage: with a difficulty range of only −0.346 to +0.242 logit (scientific literacy) and −0.046 to +0.270 logit (creativity), both instruments fail to challenge respondents at sufficiently varied ability levels. These limitations are acknowledged and their implications for future instrument revision are addressed in the conclusion.

On the creativity instrument, item CR2 ("I can quickly answer questions in discussion") was the most difficult (+0.270 logit), while CR15 ("I often ask questions about things I do not understand") was the easiest (−0.046 logit). The comparatively greater difficulty of fluency items (CR1–CR3; mean logit ≈ +0.20) and originality items (CR7–CR9; mean ≈ +0.18) relative to curiosity and risk-taking items suggests that the capacity to generate ideas spontaneously and originally is the least developed dimension of creativity. Rafik et al. (2022) and Amriani et al. (2024) both concluded that fluency and originality demand a learning environment that explicitly creates space and appreciation for divergent, unconventional thinking conditions rarely present in teacher-centered biology classrooms.

Reliability and separation

Table 4 summarises the overall psychometric indicators of both instruments. Both instruments demonstrated excellent psychometric quality. Cronbach's Alpha coefficients reached 0.959 for scientific literacy and 0.947 for creativity, significantly exceeding the minimum threshold of 0.70 (Nunnally & Bernstein, 1994). In Rasch terminology, person reliability of 0.991 for both scales indicates near-perfect measurement consistency. The person separation index of 10.39 for both scales confirms, according to Bond and Fox (2015), that the instruments can differentiate respondents into distinct ability strata with high precision a prerequisite for using these instruments as diagnostic tools to design differentiated instruction.

The mean person ability logits—+0.012 for scientific literacy and −0.129 for creativity are both near the item calibration center (0.0 logit). Wright and Masters (1982) explained that logit values near zero indicate good instrument targeting: student ability and item difficulty overlap so the instrument is neither too easy nor too difficult for this population. This targeting quality is further confirmed by the Wright Map (Table 5).

Table 4 Psychometric indicators of scientific literacy and creativity instruments

Indicator	Scientific literacy	Creativity	Criterion
Cronbach alpha	0.959	0.947	≥ 0.70 (Nunnally. 1994)
Mean person ability (logit)	+0.012	−0.129	Near 0.0
SD person ability (logit)	0.782	0.675	—
Person separation	10.39	10.39	≥ 2.0
Person reliability (Rasch)	0.991	0.991	≥ 0.80
Mean item infit MNSQ	0.372	0.381	0.6–1.4
No. of misfitting items	0	0	0
Correlation SL–CR (Pearson)	0.903	—	—

Note: Criteria follow Nunnally & Bernstein (1994) for Cronbach Alpha; Bond & Fox (2015) for Rasch indices.

Table 5 Wright map: distribution of person ability and item difficulty (scientific literacy)

Logit	Person (X=±3 students) | Items
+0.30	XXXXXXXXX | SL6 SL2
+0.20	XXXXXXXXXXXXXX | SL5 SL16 CR1 CR2 CR8
+0.10	XXXXXXXXXXXXXXXXX | SL7 SL9 CR3 CR4 CR5 CR7 CR9 CR16
0.00	XXXXXXXXXXXXXXXX | SL1 SL3 SL8 SL17 CR10–CR15 CR17 CR18 [Mean Item]
−0.10	XXXXXXXXXXXXX | SL4 SL10 SL11 SL13 SL15
−0.20	XXXXXXXXX | SL12 SL14
−0.35	XXXXX | SL18

Note: X = approximately ±3 students; item mean calibrated to 0.0 logit. Items shown at their estimated difficulty positions.

Wright map (Person–Item Map)
The Wright Map in Table 5 visualizes the joint distribution of person ability (left) and item difficulty (right) on a shared logit continuum. The spread of students across the −0.35 to +0.30 logit range, centered near the item cluster, indicates good targeting. The most difficult items (SL6, SL2, CR2) appear at the top, corresponding to the ability range of the most proficient students. The easiest items (SL18, SL14) occupy the bottom, accessible even to lower-ability students. This structure confirms that the instrument is well-calibrated to discriminate meaningfully across the full ability spectrum of this student population.

Dimensional profile
In scientific literacy, the dimensions of attitudes toward science (M/item=3.12) and science context (M/item=3.06) recorded the highest per-item means, while science process (M/item=2.87) and content (M/item=2.95) were lower. This pattern carries a critical pedagogical implication: students are relatively comfortable expressing positive dispositions toward science and relating science to life contexts, yet struggle when asked to demonstrate actual scientific skills such as designing experiments and analysing evidence. This resonates with Holbrook and Rannikmae's (2018) distinction between students who are science-aware and those who are truly science-literate. Puspitarini et al. (2025) demonstrated that socio-scientific issue-based approaches effectively bridge the context and process science dimensions simultaneously, suggesting a practical instructional response.

In creativity, dimensions of curiosity (M/item=2.96) and risk-taking (M/item=2.94) were highest, while fluency (M/item=2.80) and originality (M/item=2.80) were lowest. The low originality and fluency scores require serious attention, as these dimensions constitute the core of meaningful creativity (Torrance, 1966). Juliastari et al. (2022) showed that project-based learning using a science-technology-society approach significantly improved students' scientific creativity, including originality. Handayani et al. (2023) similarly found that bioplastic preservation project-based learning yielded the greatest creativity gains in elaboration and originality. Afifah et al. (2025) confirmed that PjBL-STREAM-based learning most strongly improved exactly these dimensions when students were actively challenged to innovate.

Comparison of abilities across classes
Rasch logit estimates enabled invariant ability comparisons across classes. Class X E10 led with the highest mean logits for scientific literacy (+0.261) and creativity (+0.065), followed by X E8 (SL: +0.074; CR: −0.014), and X E7 registered the lowest (SL: −0.145; CR: −0.280). The gap between X E10 and X E7 reached 0.406 logits for scientific literacy a difference that Bond and Fox (2015) characterise as substantially meaningful within Rasch measurement, equivalent to approximately half a standard unit of ability. Agustina et al. (2022) found that consistent, well-structured blended project-based learning significantly reduced inter-group competency disparities by providing all students with equal developmental opportunities, underscoring the importance of pedagogical standardisation across classes.

Correlation of scientific literacy and creativity
The Pearson correlation between total scientific literacy and creativity scores was very strong ($r=0.903$; $p<0.001$), surpassing values reported in comparable prior studies. Hu et al. (2026) established. that scientific literacy is a robust predictor of scientific creativity because both competencies rely on critical thinking, evidence-based reasoning, and problem-solving. In the ecosystem context of this study, students who could mechanistically explaining eutrophication (a science process indicator) also consistenly proposed innovative solutions (originality and elaboration indicators). Komalasari et al. (2024) observed the same bidirectional dynamic in Problem-Oriented Project Based Learning: designing creativity-enhancing projects automatically elevated scientific literacy, and vice versa, because rigorous inquiry and creative thinking are mutually reinforcing.

This symbiotic relationship has direct implications for curriculum design. Rahmah et al. (2026) demonstrated that Microgreens project-based learning integrated with E-STREAM (Environmental, Science, Technology, Religion, Engineering, Arts, Mathematics) simultaneously and significantly improved both scientific literacy and creativity precisely because the integrative approach developed both competencies in a single authentic context. Husni (2023) extended this finding to bioentrepreneurship-based learning, where integrating science, creativity, and socioeconomic context simultaneously elevated science literacy, creativity, and intrinsic motivation. These converging findings strongly argue that instructional designs separating scientific literacy development from creativity cultivation are both inefficient and pedagogically misaligne.

Response category distribution
The frequency distribution of responses per Likert category is presented in Table 6. Category 3 (Neutral/Somewhat Agree) dominated responses for both scientific literacy (45.0%) and creativity (49.7%). Baumgartner and Steenkamp (2001) identified this as central tendency bias the systematic avoidance of extreme scale positions which is common in Likert instruments and reflects respondents' uncertainty rather than deliberate mid-point selection. In this study, the dominance of moderate responses is consistent with the students' overall 'moderate' ability profile from Rasch analysis, it suggests that many

students lack strong self-efficacy beliefs in their scientific and creative competencies. Notably, the proportion of responses in categories 4 and 5 was higher for scientific literacy (25.5%) than creativity (18.5%), reinforcing the pattern that students feel more confident about their science knowledge than their creative capacities.

Collectively, the findings point to four interconnected pedagogical priorities. First, the identification of science process skills, particularly inquiry design (SL6), as the most difficult items necessitates structured, experience-based inquiry activities. Eliza et al. (2025), concluded a systematic review, that Project-Based Learning is the most effective approach for developing scientific literacy across educational levels. Second, the low scores on originality and fluency call for learning environments that explicitly reward divergent thinking; Farhanudin and Arifah (2026) found that bioentrepreneurship-based PjBL most strongly developed these creativity dimensions. Third, the significant inter-class ability disparities require continuous Rasch-based formative assessment, as Murniati et al. (2023) showed that sustained, evidence-based learning is essential for building the conceptual mastery underpins retention of scientific literacy. Fourth, technology integration, such as AR-enhanced e-modules (Sulisetijono et al., 2023) and AI-scaffolded project planning (Ramadhani et al., 2025), can serve as an effective bridge between science process and creativity development when implemented with appropriate pedagogy. Taken together, these priorities point to the development of a STEAM-based learning module that integrates authentic ecosystem contexts, open-ended inquiry, and creative project tasks as the most responsive instructional approach for the profile of strengths and weaknesses identified in this study

Table 6 Frequency distribution and percentage of responses per category

Cat.	Label	f (SL)	% (SL)	f (CR)	% (CR)
1	Strongly disagree	48	2.5%	58	3.0%
2	Disagree	525	27.0%	560	28.8%
3	Somewhat agree / neutral	875	45.0%	967	49.7%
4	Agree	365	18.8%	280	14.4%
5	Strongly agree	131	6.7%	79	4.1%
Total	**—**	**1.944**	**100%**	**1.944**	**100%**

Note: Total responses = 108 students × 18 items = 1.944 per instrument. f = frequency.

D. Conclusion

This study successfully analyzed the scientific literacy and creativity of 108 10th-grade students across three study groups using Rasch Partial Credit Model-validated instruments, yielding several significant findings. Both instruments demonstrated high person reliability (scientific literacy α=0.959; creativity α=0.947; person reliability=0.991; person separation=10.39), confirming strong ability-ordering precision. However, a critical psychometric limitation must be acknowledged: all 36 items exhibited systematic overfit infit MNSQ values well below the lower productive boundary of 0.6 (scientific literacy: mean=0.372, range 0.20–0.61; creativity: mean=0.381, range 0.28–0.49), indicating pervasive inter-item redundancy and insufficient construct breadth across both instruments. No items exceeded the upper misfit threshold of 1.4. This overfitting pattern also inflates Cronbach alpha beyond what genuine construct validity warrants. Future instrument development must prioritise expanding item difficulty range (target: at least 2–4 logit units), introducing semantically differentiated items within each dimension, and incorporating reverse-scored or scenario-based stimuli to generate the stochastic response variation required for valid Rasch-based inference. Students' mean scientific literacy ability (+0.012 logit) was marginally higher than creativity (−0.129 logit), with both values near the instrument calibration center indicating good targeting. Class X E10 consistently outperformed the other groups on both constructs, highlighting inter-class disparities that demand standardized, evidence-based instructional approaches. The very strong correlation between scientific literacy and creativity ($r=0.903$; $p<0.001$) confirms that these competencies are deeply intertwined and should be developed in an integrated, rather than separate, fashion within biology learning designs. Specifically, the identified weaknesses in science process skills (SL6 as the most difficult item) and creativity originality/fluency (lowest per-item means) provide a precise diagnostic target for instructional intervention: the development of a STEAM-integrated learning module grounded in authentic ecosystem contexts, open-ended inquiry, and project-based creative tasks is the most evidence-aligned treatment for the student profile identified in this study. Future research is recommended to develop, implement, and experimentally evaluate such a module, using the Rasch-validated instruments employed here as pre- and post-assessment tools to measure competency growth with invariant, sample-independent precision.

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