



Development and Validation of ComicSIM on Volcanic Activity With a PISA-Aligned Assessment Tool

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Abstract

Objectives. Comic-based instructional materials demonstrate measurable gains in student engagement and scientific literacy; yet few studies integrate comic formats with Strategic Intervention Materials (SIMs) and PISA-aligned assessment for Earth Science in Philippine secondary schools. This study developed and validated ComicSIM, a comic-based SIM on volcanic activity for Grade 9 Science, alongside a PISA-aligned assessment tool comprising 20 items across eight lessons.

Materials and Methods. A descriptive-developmental design was used. Five expert jurors holding graduate qualifications in science education or curriculum development, with at least five years of professional experience, independently evaluated both instruments. ComicSIM was assessed across seven sub-criteria using a 5-point rubric; inter-rater agreement was measured using Fleiss' Kappa. The PISA-aligned assessment tool was evaluated using a 15-item alignment instrument with a 4-point scale; internal consistency was assessed using Cronbach's Alpha.

Results. ComicSIM achieved a weighted mean of 4.5 (Excellent) and a Fleiss' Kappa of 0.70 (substantial agreement). The PISA-aligned assessment tool obtained an alignment mean of 3.8 (Strongly Agree), a dimension mean of 4.93 (Excellent), and a Kappa of 0.87 (almost perfect agreement). Cronbach's Alpha of 0.88 confirmed strong internal consistency.

Conclusions. Both instruments are expert-validated, reliable, and suitable for use in advancing PISA-aligned scientific literacy instruction in Philippine secondary science classrooms, pending confirmation of classroom effectiveness through empirical research.

Keywords: comicSIM, strategic intervention material, PISA, volcanic activity, Grade 9 science.

Introduction

The Philippines occupies a geographically hazardous position at the convergence of three major tectonic plates, placing it firmly within the Pacific Ring of Fire. Volcanic eruptions constitute one of the most severe natural hazard threats faced by Filipino communities, making scientific understanding of volcanic processes both academically and practically consequential (Aghaei et al., 2018; German et al., 2022; Kurata et al., 2022). Yet despite this pressing local relevance, Filipino students continue to underperform on international science assessments. In the 2018 PISA cycle, the Philippines scored 357 in Science, placing it well below the OECD average and underscoring systemic gaps in science learning outcomes at the basic education level (DepEd, 2018). The need for innovative instructional materials that simultaneously build scientific literacy and sustain student

engagement has consequently become a recognised priority in Philippine science education research (Cahyana et al., 2019; Degorio & Langub, 2025).

These outcomes have prompted educators and researchers to explore more effective and engaging instructional approaches. Strategic Intervention Materials (SIMs), defined as structured, teacher-crafted resources designed to remediate least-mastered learning competencies, have become widely adopted in Philippine classrooms as targeted tools for improving student performance (Dacumos, 2016; Gabucan & Sanchez, 2021). Meta-analytic evidence confirms that both paper-based and digital SIMs demonstrate large effect sizes in improving science and mathematics outcomes among Filipino learners (Borabo & Dio, 2025). However, most existing SIMs rely on conventional text-based formats that may not adequately stimulate student engagement or leverage the motivational potential of visual media.

Comics represent an underutilized educational medium in the Philippine context, despite substantial evidence of

their effectiveness in science instruction internationally. Integrating narrative with sequential visual imagery, comics create a dual-coding effect that deepens conceptual understanding and sustains motivation, consistent with Mayer's (2009) Cognitive Theory of Multimedia Learning and with constructivist perspectives on active meaning-making through contextualized narrative (Bruner, 1990; Vygotsky, 1978). Research consistently demonstrates that comic-based science materials improve student engagement, scientific vocabulary acquisition, and conceptual comprehension (Fitria et al., 2023; Hosler & Boomer, 2011; Tatalovic, 2009). In the Philippine setting specifically, comic-based instructional materials combining SIM structures with comic formats have shown positive learning attitudes and significant gains in science achievement (Molina & Cadorna, 2025; Samosa, 2021).

Simultaneously, growing attention to PISA-aligned assessments reflects a broader imperative to equip Filipino students with the scientific literacy competencies demanded by the 21st century. The PISA 2022 science framework assesses students' capacity to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence in real-world contexts (OECD, 2023). Integrating these competencies into locally developed instructional materials represents a powerful mechanism for bridging the gap between national curriculum delivery and international benchmarks (Valio et al., 2025).

Comics, defined as a medium combining sequential art with narrative text, have gained increasing recognition as legitimate instructional tools in science education (Eisner, 2008). A systematic review of 20 studies found that comics significantly enhance student motivation, engagement, and conceptual understanding while promoting active participation and fostering critical thinking skills (Rasmet et al., 2025). This position is theoretically grounded in Mayer's (2009) Cognitive Theory of Multimedia Learning, which posits that the simultaneous processing of words and pictures through dual-coding enhances learning outcomes by reducing cognitive load and fostering deeper encoding. Constructivist theory similarly supports comic-based instruction: Bruner (1990) argued that narrative is a fundamental mode through which learners construct meaning, while Vygotsky (1978) emphasized the role of culturally situated tools in scaffolding conceptual development. Comics that embed scientific concepts within culturally resonant storylines align directly with these principles.

Empirical support for comic-based science instruction is well established. Hosler and Boomer (2011) found that students learning from comics outperformed those using conventional text resources in measures of conceptual understanding. Tatalovic (2009) observed that science comics facilitate science literacy by rendering technical vocabulary accessible through narrative contexts. More recent evidence from Southeast Asia corroborates these findings: Fitria et al. (2023) demonstrated that digital comic teaching materials significantly improved scientific literacy scores among elementary students in Indonesia, while Fananta et al. (2019) found that inquiry-based science comics enhanced primary learners' scientific literacy across three dimensions. Constructing socio-scientific issue literacy through comics has further been shown to foster critical thinking and equip

students to engage with complex real-world challenges (Rosidah et al., 2022). Valente and Faria (2026) extend this argument to pre-service teacher education, finding that future elementary teachers who engaged with science comics developed more positive science identity attitudes, an outcome with downstream implications for classroom instruction.

In the Philippine context, comic-based SIMs have yielded particularly promising results. Samosa (2021) reported high positive attitudes and significant pre-test to post-test gains among students exposed to CoSIM, a comics-plus-SIM hybrid, in Biology. Molina and Cadorna (2025) demonstrated that comic-based learning materials enhanced understanding, attitude, and skills in Physics among Filipino high school students. These locally grounded findings affirm that comics, when integrated with SIM structures, constitute a culturally resonant and pedagogically effective modality for Philippine science instruction.

Strategic Intervention Materials are teacher-made instructional tools specifically designed to address identified learning gaps in students who have not mastered targeted competencies. Within the Philippine Department of Education framework, SIMs function as supplementary resources structured around a guide card, activity cards, assessment cards, and an enrichment card, providing scaffolded and self-directed remediation (Dacumos, 2016). A 2025 meta-analysis of 15 studies on SIM effectiveness in science and mathematics confirmed that SIMs produce large effect sizes regardless of format, with paper-based SIMs yielding an effect size of 1.67 and digital SIMs yielding 1.34, establishing their value as remedial tools across the K-12 spectrum (Borabo & Dio, 2025).

Development and validation studies of SIMs in Philippine science consistently report expert-validated materials as highly acceptable in content and technical aspects (Lituanas & Dela Cruz, 2024; Samosa, 2021). In instructional material development research, expert validation by qualified jurors constitutes the accepted and methodologically defensible first phase of the development cycle, establishing content validity and design quality before proceeding to learner-facing trials (Branch & Varank, 2009; Gall et al., 1996). This phased approach reflects the understanding that materials with unverified content accuracy or design integrity should not be deployed in classrooms, making expert validation an essential prerequisite rather than a substitute for subsequent effectiveness studies. However, most existing SIMs do not explicitly align their assessment components with international literacy frameworks such as PISA, limiting their utility for preparing students for globally benchmarked competencies.

Earth science topics such as volcanic activity present particular instructional challenges because they require students to reason across multiple spatial and temporal scales, connect abstract geological processes to observable phenomena, and apply scientific evidence to real-world risk decisions (Francek, 2013). Research on geoscience education consistently finds that students hold persistent misconceptions about volcanic processes, including the belief that eruptions are random or unpredictable, and that human activity plays no role in volcanic risk exposure (King, 2010). Narrative-based and contextualized instructional approaches

have been shown to be especially effective at addressing these misconceptions by grounding abstract processes in relatable human consequences (Demirci & Okur, 2021; Korur et al., 2025). For Filipino students in particular, volcanic activity is not an abstract academic topic but a lived environmental reality, making contextualized instructional materials such as ComicSIM especially well-suited to this content domain.

The PISA 2022 science framework defines scientific literacy as the capacity to engage with science-related issues and use scientific knowledge and reasoning to explain phenomena, evaluate evidence, and make informed decisions in real-world contexts (OECD, 2023). The Philippines' 2018 PISA result of 357 in Science placed it among the lowest-scoring participants, reflecting systemic challenges in developing the inquiry-based, evidence-evaluating competencies that PISA measures (DepEd, 2018). Valio et al. (2025) argued that integrating PISA-aligned assessments into local instructional materials offers a direct mechanism for building these competencies within the K-12 curriculum. Instructional materials that contextualize PISA competencies within locally relevant phenomena, such as volcanic activity in the Philippine archipelago, address a critical pedagogical need by linking scientific reasoning to students' lived experience. The PISA 2022 framework identifies real-world contexts, including geohazard risk and environmental sustainability, as primary assessment domains, making volcanic activity an ecologically valid and curriculum-aligned content focus (OECD, 2023).

Despite the documented benefits of both SIMs and comics in Philippine science education, no study to date has systematically combined the two within a PISA-aligned framework for Earth science content. This study addresses that gap by developing and validating ComicSIM, a comic-based SIM focused on volcanic activity for Grade 9 Science, along with an accompanying PISA-aligned assessment tool. The study is guided by three research questions: (1) How do expert jurors assess ComicSIM across seven sub-criteria of instructional material quality? (2) What PISA-aligned assessment tool can be developed from the content of ComicSIM? (3) How reliable and valid are ComicSIM and the PISA-aligned assessment tool as evaluated through expert judgment and statistical analysis?

Materials and Methods

Study Participants

Five expert jurors validated both ComicSIM and the PISA-aligned assessment tool. Jurors were identified through purposive sampling based on three criteria: (a) a graduate degree (master's or doctoral level) in science education, curriculum development, or a closely related field; (b) a minimum of five years of professional experience in secondary science teaching, instructional material development, or educational assessment; and (c) familiarity with the Philippine K-12 Science curriculum and DepEd instructional material standards. To manage potential institutional bias, jurors were drawn from schools and institutions external to the researchers' institution. No juror had prior access to the ComicSIM drafts before the validation process. Table 1 presents a summary of juror profiles.

Table 1. Summary of Expert Juror Profiles

Juror	Highest Qualification	Area of Expertise	Years of Experience
J1	Doctor of Education	Science Education and Curriculum	15
J2	Master of Arts in Education	Instructional Material Development	10
J3	Doctor of Philosophy	Educational Assessment and Measurement	18
J4	Master of Arts in Teaching	Secondary Science Teaching (Earth Science)	8
J5	Doctor of Education	Science Pedagogy and Curriculum Evaluation	12

Study Organization

This study employed a descriptive-developmental research design. The developmental phase involved the systematic creation of ComicSIM, a comic-based Strategic Intervention Material on volcanic activity for Grade 9 Science, together with a 20-item PISA-aligned assessment tool structured across eight thematic lessons. The descriptive phase involved expert evaluation of both instruments through juror validation. Consistent with established practice in instructional material development research, expert validation constitutes the appropriate first phase of the development cycle, generating evidence of content validity and design quality prior to classroom deployment (Branch & Varank, 2009; Gall et al., 1996). A classroom-based effectiveness study involving student participants is identified as the necessary and immediate next phase of this programme of research.

ComicSIM was developed in comic strip format based on the Grade 9 Science Most Essential Learning Competencies (MELCs) related to volcanic activity. The material follows a continuous fictional narrative set in a volcanic hazard context, incorporating characters who navigate scientific, ethical, and social dimensions of volcanic risk. The storyline was designed to integrate PISA scientific competency domains, including applying scientific knowledge to real-world issues, distinguishing scientific evidence from personal belief, and engaging in ethical reasoning under disaster conditions. Eight lessons were embedded within the narrative, each mapped to a specific PISA competency and assessed through corresponding items in the accompanying assessment tool. Figure 1 presents sample pages from the developed ComicSIM.

Two validation instruments were employed. The Comics Evaluation Rubric (CER) is a researcher-constructed 7-criterion evaluation tool developed through a review of existing rubrics for instructional comics (Rasmet et al., 2025; Tatalovic, 2009), SIM evaluation frameworks used in Philippine DepEd practice (Dacumos, 2016; Lituanas & Dela Cruz, 2024), and Mayer's (2009) Cognitive Theory of Multimedia Learning. The seven criteria—(a) content accuracy and relevance, (b) clarity and readability, (c) visual appeal and creativity, (d) interactivity and engagement, (e) pedagogical effectiveness, (f) cultural and contextual relevance, and (g) assessment and feedback—were selected to capture the dual requirements of ComicSIM as both a

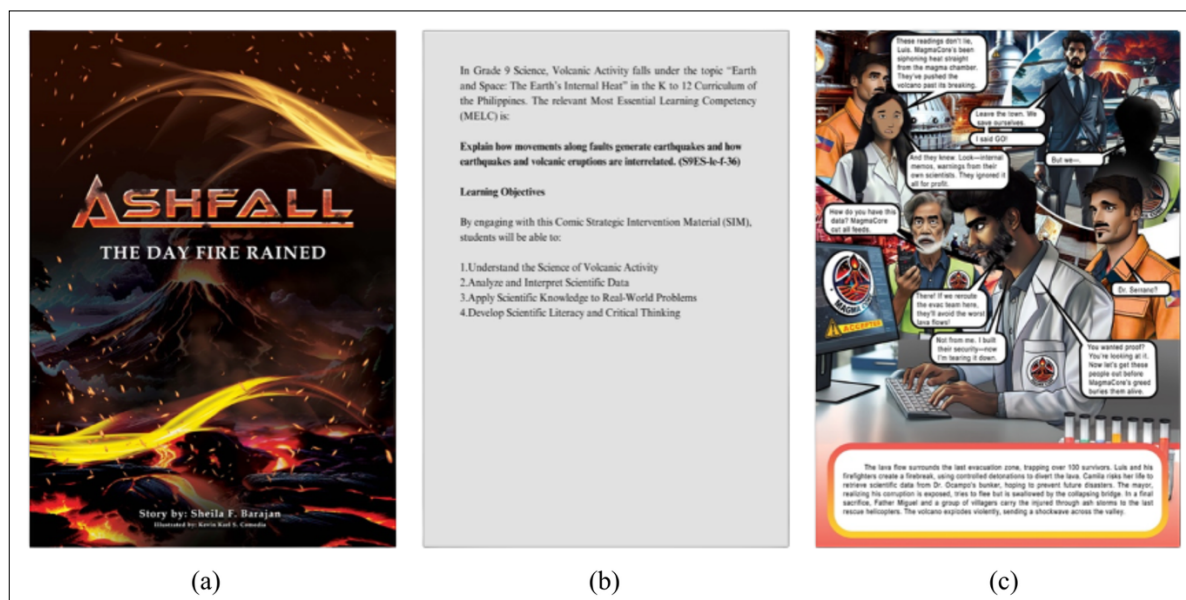


Fig. 1. Structural components of the developed Comic Strategic Intervention Material (comicSIM) on volcanic activity: (a) front cover page showing the Title, (b) guide card displaying the target Grade 9 Science competency and explicit learning objectives, and (c) sample narrative comic panel integrating scientific concepts within the storyline.

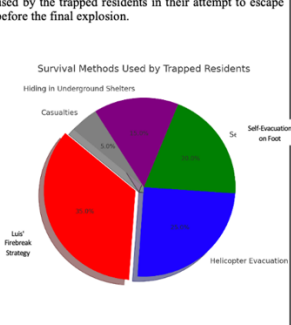
ITEM #1 Question 1/2 Why is it important to base disaster response decisions on scientific evidence rather than political opinions? A. Scientific evidence is based on measurable data and patterns, making predictions more reliable. B. Political decisions are always correct because leaders have more experience. C. The public should always believe government officials, even when they ignore expert warnings. D. Volcanoes erupt randomly, so there is no way to predict disasters using science. Question 2/2 As Mount Sombra shows signs of an impending eruption, strange events occur in San Esperanza: wells dry up, small earthquakes increase, and animals flee the area. What is the most scientific explanation for these warning signs? A. The volcano is consuming underground water, causing wells to dry up. B. Animals have a special ability to sense future events, so they flee before any disaster. C. Rising magma increases pressure, triggering earthquakes and affecting groundwater. D. These events are coincidences and do not indicate any volcanic activity.		Evaluating Scientific Evidence vs. Political Decisions  Dr. Camila Reyes, a volcanologist, presents scientific evidence that Mount Sombra is showing signs of an imminent eruption. However, Mayor Esteban Cruz refuses to order an evacuation, prioritizing tourism and business over public safety. Despite observable warning signs, such as animals fleeing and increasing seismic activity, the town council is divided—some leaders believe in science, while others dismiss it as a false alarm.	Based on your result, explain whether they had enough time and how emergency response strategies could be improved. ITEM #7 Question 1/3 Based on the pie chart, which survival strategy was the most effective in saving the trapped residents? A. Helicopter Evacuation B. Luis' Firebreak Strategy C. Self-Evacuation on Foot D. Hiding in Underground Shelters Question 2/3 Camila had to decide whether to retrieve scientific data from Dr. Ocampo's bunker or immediately evacuate. If you were in her situation, what factors should you consider before making a decision? A. The importance of scientific data in preventing future disasters vs. the immediate danger of staying behind. B. The financial value of the data compared to the town's economic losses. C. The possibility of the volcano stopping the eruption suddenly. D. The potential of blaming someone else if the mission fails. Question 3/3 The pie chart shows different survival methods used by trapped residents during the volcanic eruption. If a similar eruption occurs in the future, which survival method should emergency planners focus on improving to increase survival rates? A. Helicopter evacuation, since it saved a quarter of the trapped residents.	Survival Methods Used by Trapped Residents As Mount Sombra erupts violently, over 100 survivors are trapped in the last evacuation zone, surrounded by lava flows. Luis and his firefighters use controlled detonations to create a firebreak, diverting the lava and buying time for escape. Meanwhile, Camila risks her life retrieving scientific data from Dr. Ocampo's bunker, hoping to use it to prevent future disasters. The corrupt mayor, whose actions endangered the town, tries to flee but is killed when the bridge collapses. In an ultimate act of heroism, Father Miguel and a group of villagers carry the injured through thick ash to reach the last rescue helicopters before a massive shockwave shakes the valley. This pie chart represents the various survival methods used by the trapped residents in their attempt to escape before the final explosion. Survival Methods Used by Trapped Residents Hiding in Underground Shelters Casualties Self-Evacuation on Foot Helicopter Evacuation Luis' Firebreak Strategy 
ITEM #2 Question 1/2		Scientific Literacy & Critical Thinking As Mount Sombra shows clear warning signs of an eruption, Father Miguel urges his followers to stay.		

Fig. 2. Sample assessment layout from the developed PISA-Aligned assessment tool illustrating the integration of scientific literacy and critical thinking items: (left) multiple-choice questions evaluating conceptual understanding of volcanic warning signs, and (right) an integrated data-analysis item requiring students to interpret graphical evidence (pie chart) regarding disaster response strategies.

comic-format material and a structured SIM. Content validity of the CER was established through a two-stage process: (1) independent review of criteria and descriptors by a measurement specialist for relevance, clarity, and construct

alignment, and (2) informal piloting with two science educators external to the study prior to formal use. Jurors rated each criterion on a 5-point scale (5 = Excellent, 4 = Good, 3 = Satisfactory, 2 = Needs Improvement, 1 = Poor).

Table 2. Matrix of Item Distribution of the Assessment Tool

Lesson	Lesson Title	PISA Competency	No. of Items	Item Numbers
1	Volcanic Hazards and Predictions	Applying scientific knowledge to real-world issues	2	1, 2
2	Human Responses and Scientific Evidence in Disaster Preparedness	Distinguishing scientific evidence from personal beliefs	2	3, 4
3	Ethical Decision-Making and Disaster Risk Reduction	Scientific reasoning with social and ethical considerations	2	5, 6
4	Survival Skills and Risk Reduction During Eruptions	Explaining phenomena scientifically	3	7, 8, 9
5	Human Activities and Their Impact on Volcanic Systems	Interpreting data and evidence scientifically	1	10
6	Volcanic History, Warnings, and Emergency Response	Evaluating and designing scientific inquiry	4	11, 12, 13, 14
7	Planning for Eruptions: Survival Strategies and Safety Measures	Analyzing data and making evidence-based decisions	3	15, 16, 17
8	Geothermal Energy, Volcanic Risk, and Sustainable Development	Applying scientific principles to real-world situations	3	18, 19, 20

The PISA Science Framework Alignment Scale (PISFAS) is a 15-item evaluation instrument whose items were derived directly from the five core competency domains of the PISA 2022 Science Framework: Scientific Competencies, Scientific Knowledge, Contexts, Science Identity, and Environmental Science Competencies (OECD, 2023). Items were organized under four constructs: (1) relevance to the PISA Science Literacy Framework, (2) cognitive demand and inquiry-based learning, (3) format and engagement, and (4) overall PISA alignment. Content validity of the PISFAS was established through review by the measurement specialist, who verified the alignment of each item against the corresponding PISA framework competency. Ratings used a 4-point scale (4 = Strongly Agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree). Internal consistency of the PISFAS in the present administration yielded Cronbach's Alpha = 0.88, confirming strong reliability for this use.

The PISA-aligned assessment tool comprises 20 items distributed across eight thematic lessons embedded within the ComicSIM narrative. Table 2 presents the mapping of lessons to PISA competencies and item distribution. Each lesson was constructed to address a distinct PISA scientific competency, ensuring that the assessment tool evaluates the full spectrum of scientific literacy skills outlined in the PISA 2022 framework. Item contexts draw directly from the ComicSIM narrative, requiring students to apply scientific reasoning to situations, characters, and decisions depicted in the comic (Figure 2). This contextual embedding is intentional: assessment items anchored in a narrative stimulus that students have already engaged with are hypothesized to reduce construct-irrelevant variance from unfamiliar item contexts, a recognized source of measurement error in PISA-style assessments (OECD, 2023).

Statistical analysis

Mean and standard deviation were computed to describe the central tendency and spread of juror ratings. Fleiss' Kappa (Fleiss, 1971) was calculated to determine inter-rater agreement beyond chance, interpreted using the Landis and Koch (1977) benchmarks: 0.00 to 0.20 as slight, 0.21 to 0.40

as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial, and 0.81 to 1.00 as almost perfect agreement. Cronbach's Alpha was computed to assess the internal consistency of the jurors' ratings on the PISA alignment evaluation sheet. All computations were performed using Jamovi (Version 2.4; The jamovi project, 2022).

Results

Table 3 presents the juror ratings of ComicSIM across its seven evaluative sub-criteria. All five jurors completed the evaluation independently, and no rating was changed following consultation.

ComicSIM received an overall weighted mean of 4.5 (Excellent) across all seven sub-criteria, with an overall Fleiss' Kappa of 0.70 indicating substantial agreement among the five jurors. The highest-rated dimension was Assessment and Feedback ($M = 4.8$, Excellent; $\kappa = 0.60$, Moderate agreement), reflecting strong consensus on the material's integration of meaningful evaluation tasks and feedback mechanisms. Content Accuracy and Relevance, Interactivity and Engagement, and Cultural and Contextual Relevance each received a weighted mean of 4.6 (Excellent), confirming that ComicSIM delivers scientifically accurate content within an engaging and culturally situated format. Visual Appeal and Creativity and Pedagogical Effectiveness were both rated 4.4 (Good), while Clarity and Readability received a rating of 4.0 (Good).

The pattern of Kappa values warrants careful interpretation. The fair Kappa values observed for most sub-criteria ($\kappa = 0.30$ to 0.40), despite uniformly high means, are consistent with a well-documented ceiling effect in expert validation studies: when all raters cluster at the upper end of a rating scale, chance-corrected agreement statistics such as Kappa are mathematically suppressed even when raters are highly consistent in their overall evaluative judgements (Feinstein & Cicchetti, 1990; McHugh, 2012). This phenomenon, sometimes termed the Kappa paradox, does not indicate disagreement among jurors; rather, it reflects the statistical consequence of near-unanimous high ratings. The Clarity and Readability dimension illustrates this point from

Table 3. Inter-Rater Agreement of ComicSIM Across Sub-Criteria

Criterion	Weighted Mean	Interpretation	Fleiss' Kappa (κ)	Agreement Level
Content Accuracy and Relevance	4.6	Excellent	0.40	Fair
Clarity and Readability	4.0	Good	1.00	Almost Perfect
Visual Appeal and Creativity	4.4	Good	0.30	Fair
Interactivity and Engagement	4.6	Excellent	0.40	Fair
Pedagogical Effectiveness	4.4	Good	0.40	Fair
Cultural and Contextual Relevance	4.6	Excellent	0.40	Fair
Assessment and Feedback	4.8	Excellent	0.60	Moderate
Overall	4.5	Excellent	0.70	Substantial

Table 4. Validation of the Developed PISA-Aligned Assessment Tool

PISA Construct	Items	Mean Score Range	Interpretation
Relevance to PISA Science Literacy Framework	1 to 4	3.6 to 4.0	Strongly Agree
Cognitive Demand and Inquiry-Based Learning	5 to 8	3.8 to 4.0	Strongly Agree
Format and Engagement	9 to 11	3.6	Strongly Agree
Overall Alignment with PISA	12 to 15	3.8 to 4.0	Strongly Agree
Total (All Items)	1 to 15	3.8	Strongly Agree

a different angle: its Kappa of 1.00 indicates that all five jurors assigned exactly the same score to this criterion, resulting in perfect agreement at a mean of 4.0. This pattern confirms that while ComicSIM's readability is consistently rated as Good, it is an area where targeted revision could elevate ratings to the Excellent range observed in other criteria.

Juror qualitative feedback reinforced these quantitative findings. Evaluators commended the material for its scientific accuracy, balance of scientific terminology with narrative storytelling, and its capacity to represent diverse perspectives including ethical and social considerations surrounding volcanic hazards. Areas recommended for refinement included increased localization of the narrative setting to enhance contextual relevance for learners from provincial Philippine communities such as Masbate, and the addition of greater narrative tension in the pre-eruption sequence to heighten dramatic engagement.

Table 4 presents juror ratings on the 15-item PISA alignment evaluation instrument.

The assessment tool received an overall mean rating of 3.8 (Strongly Agree) across all four PISA constructs, confirming strong expert consensus on its alignment with the PISA Science Literacy Framework. Items assessing Relevance to PISA (items 1 and 2) and Overall Alignment with PISA (item 12) received the highest scores ($M = 4.0$), reflecting unanimous agreement on their framework fidelity. Cognitive Demand and Inquiry-Based Learning items performed strongly ($M = 3.8$ to 4.0), affirming that the tool promotes higher-order thinking consistent with PISA's competency

demands. Format and Engagement items received slightly lower ratings ($M = 3.6$), with one juror assigning lower scores on items 10 and 11, citing concerns about the visual layout of contextual stimuli alongside test questions. This finding points to a specific and addressable design issue rather than a fundamental validity problem with the tool.

The PISA-aligned assessment tool achieved an overall weighted mean of 4.93 (Excellent) across all five evaluative dimensions, with overall inter-rater agreement of Kappa = 0.87 (Almost Perfect). In contrast to the ceiling-effect pattern observed in the ComicSIM validation, the high Kappa values across PISA dimensions reflect genuine and consistent consensus among jurors at near-ceiling mean levels, indicating that the assessment tool's PISA alignment is clearly evidenced and uniformly recognized by independent evaluators. The Contexts dimension received a perfect score ($M = 5.00$, $\kappa = 1.00$), confirming unanimous consensus that ComicSIM's narrative effectively embeds PISA-type real-world contexts. Scientific Competencies, Scientific Knowledge, and Science Identity dimensions each yielded near-perfect scores ($M = 4.93$, $\kappa = 0.87$). Environmental Science Competencies produced slightly lower inter-rater agreement ($M = 4.87$, $\kappa = 0.73$, Substantial), suggesting minor variability in how jurors interpreted the scope of environmental science content within the volcanic activity context. Cronbach's Alpha of 0.88 confirmed strong internal consistency among the validation instrument's items, further establishing the reliability of the evaluation procedure (Table 5).

Table 5. Juror Assessment of the PISA-Aligned Assessment Tool Across Dimensions

PISA Dimension	Weighted Mean	Interpretation	Fleiss' Kappa (κ)	Agreement Level
Scientific Competencies	4.93	Excellent	0.87	Almost Perfect
Environmental Science Competencies	4.87	Excellent	0.73	Substantial
Scientific Knowledge	4.93	Excellent	0.87	Almost Perfect
Science Identity	4.93	Excellent	0.87	Almost Perfect
Contexts	5.00	Excellent	1.00	Almost Perfect
Overall	4.93	Excellent	0.87	Almost Perfect

Note. Cronbach's Alpha = 0.88. Kappa benchmarks follow Landis and Koch (1977).

Discussion

The findings of this study provide expert validation evidence for ComicSIM as a novel instructional material for Grade 9 Science in the Philippine context. It is worthy to emphasize that this evidence is restricted to expert validation, no classroom-based data on student learning outcomes were collected, and the present study does not constitute empirical evidence of instructional effectiveness. Within the scope of expert evaluation, the overall Excellent rating ($M = 4.5$) and substantial inter-rater agreement ($\kappa = 0.70$) position ComicSIM favorably alongside other expert-validated comic-based instructional materials reported in the literature. Fitria et al. (2023) similarly found strong expert validity ratings for digital science comics among Indonesian elementary students, while Samosa (2021) reported high positive attitudes toward the CoSIM hybrid format among Filipino Biology learners. The current study extends this body of validation evidence by explicitly integrating PISA-aligned competencies into the SIM structure, addressing a gap identified across most prior SIM development studies in the Philippines (Borabo & Dio, 2025).

The Excellent ratings received by Content Accuracy and Relevance, Interactivity and Engagement, and Cultural and Contextual Relevance indicate that expert evaluators judged ComicSIM to present scientifically accurate content within a format designed to engage learners and reflect their sociocultural context. This finding is consistent with Hosler and Boomer's (2011) argument that comics provide a narrative scaffold with potential to deepen engagement with scientific phenomena, and with Tatalovic's (2009) observation that narrative structures are associated with improved acquisition of technical vocabulary. It also aligns with constructivist principles: the comic's storyline is designed as a culturally familiar zone of proximal development through which students encounter volcanic science concepts in a supported and relatable context (Vygotsky, 1978). The highest-rated dimension, Assessment and Feedback ($M = 4.8$), suggests that embedding PISA-type questions directly within the comic narrative may be a promising design strategy; whether this translates into improved student metacognitive engagement requires empirical testing (Valio et al., 2025).

The Kappa values for most ComicSIM sub-criteria ranged from 0.30 to 0.40, which warrant careful contextualization. As noted in the Results, these values reflect the well-documented Kappa paradox: when expert raters consistently award high scores, the mathematical structure of chance-corrected agreement coefficients produces low Kappa values even when raters are, in practical terms, highly consistent (Feinstein & Cicchetti, 1990). This phenomenon is reported across the instructional material validation literature and does not indicate meaningful disagreement among the jurors in the present study (McHugh, 2012). The Clarity and Readability dimension, which yielded Kappa = 1.00 at a mean of 4.0, represents a distinct and instructive case: perfect agreement among jurors that the material is Good but not yet Excellent in readability. This finding converges with jurors' qualitative recommendations that dialogue and terminology be simplified for lower-performing readers, and identifies a specific, revision-ready improvement target for the next iteration of ComicSIM.

The PISA-aligned assessment tool's near-perfect inter-rater agreement ($\kappa = 0.87$) and Cronbach's Alpha of 0.88 establish strong reliability credentials that compare favorably with similar PISA-contextualized instruments in the literature (Rosana et al., 2020; Valio et al., 2025). The perfect score in the Contexts dimension ($\kappa = 1.00$, $M = 5.00$) is particularly noteworthy. It confirms that grounding assessment items within the comic narrative's volcanic hazard contexts effectively operationalizes the real-world situatedness that PISA designates as essential for measuring authentic scientific literacy (OECD, 2023). This result supports the emerging pedagogical argument that local, narrative-rich contexts may be more effective at eliciting PISA-type reasoning than decontextualized test items, because they reduce the cognitive burden of interpreting an unfamiliar stimulus while preserving the scientific reasoning demands of the task (Fananta et al., 2019; Valio et al., 2025).

Persistent misconceptions about volcanic predictability and risk are well documented in the geoscience education literature (Francek, 2013; King, 2010). ComicSIM's narrative design, which positions student-age characters as active reasoners within a volcanic emergency scenario, is theoretically consistent with findings that consequential decision-making contexts support conceptual restructuring in science education (Renouard & Mazabraud, 2018). Whether ComicSIM demonstrably reduces documented misconceptions in practice is a question that expert validation alone cannot answer; direct classroom investigation remains essential.

The slightly lower performance of the Format and Engagement construct in the PISA alignment instrument ($M = 3.6$) points to a specific and addressable design issue. One juror's lower ratings on items 10 and 11 identified concerns about the visual layout of contextual stimuli alongside test questions. Assessment tools that rely on rich narrative stimuli require careful attention to how comic panels, text, and test questions are spatially arranged on the page: stimulus material that competes visually with question text can increase cognitive load and compromise measurement validity. Revised versions should be formatted with the comic stimulus clearly separated from and preceding each question cluster, consistent with PISA item design conventions (OECD, 2023).

Taken together, the validation findings support further development and classroom testing of ComicSIM as a supplementary instructional resource in Grade 9 Science, particularly for volcanic activity units within the MATATAG curriculum. The expert evaluations indicate that ComicSIM is designed as a contextually resonant and internationally benchmarked instructional resource; however, its effectiveness for student learning must be confirmed through classroom-based research before recommendations for broader adoption can be made. Jurors' recommendation to localize narrative settings further is actionable: future versions of ComicSIM could incorporate local volcanoes such as Mayon or Bulusan, and community-specific disaster risk contexts familiar to students in volcanic hazard-prone municipalities.

Several limitations of the present study should be acknowledged. First, and most significantly, the evidence presented is restricted to expert validation and does not address student learning outcomes; claims about instructional

effectiveness cannot be derived from the present data. Second, the validation panel comprised five jurors—consistent with established practice in Philippine SIM development research (Branch & Varank, 2009; Gall et al., 1996)—but this sample size limits the generalizability of the evaluative findings. Third, the CER and PISFAS are researcher-constructed instruments whose validity in this study rests primarily on face validity review by a measurement specialist; independent psychometric validation of these instruments is a priority for future research. Fourth, the study was conducted within a specific provincial context in the Philippines, and contextual relevance ratings may not fully generalize to learners in other settings. Classroom-based effectiveness testing using the validated instruments is identified as the essential and immediate next stage of this research programme.

Conclusions

This study developed and validated ComicSIM, a comic-based Strategic Intervention Material on volcanic activity, alongside a PISA-aligned assessment tool for Grade 9 Science in the Philippines. Expert juror evaluations confirmed that ComicSIM achieved Excellent overall quality ratings with substantial inter-rater agreement, while the PISA-aligned assessment tool demonstrated near-perfect content validity and strong internal consistency. These findings establish both instruments as suitable candidates for the next phase of development research: a classroom-based quasi-experimental study in which student participants engage with ComicSIM under naturalistic instructional conditions, with learning outcomes, scientific literacy skills, and misconception reduction measured through pre-test and post-test administration of the validated assessment tool. The present study provides validation evidence only; empirical demonstration of student learning gains awaits that subsequent phase.

The contribution of the present study to Philippine science education is twofold: it provides the field with an expert-validated, PISA-aligned instructional material for a high-priority Earth science topic, and it offers preliminary evidence that the comics-plus-SIM format is a promising approach to developing internationally benchmarked science learning resources within low-resource school environments. Science teachers and curriculum developers now have access to an expert-validated tool that requires no technology infrastructure, aligns directly with the MATATAG curriculum, and situates scientific reasoning within a volcanic hazard narrative that is both locally relevant and globally benchmarked. The present study does not, however, provide evidence of classroom effectiveness; such evidence must await the quasi-experimental study identified as the next phase of this research programme.

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None.

Ethics Statement

This study involved voluntary expert evaluation by five qualified science education professionals. Participation was consensual and conducted in the jurors' professional

capacity; no signed consent form was required. No student participants, vulnerable populations, or personal data were involved, and the study did not require formal ethics committee review under the guidelines of the authors' institutions. All procedures were conducted in accordance with ethical principles for educational research, including transparency in reporting and confidentiality of individual juror identities.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AI Transparency Statement

Artificial intelligence tools were used to assist with language editing and manuscript preparation. All content, interpretations, and conclusions are the sole responsibility of the authors, who attest to the accuracy and originality of the work.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

- Aghaei, N., Seyedin, H., & Sanaeinasab, H. (2018). Strategies for disaster risk reduction education: A systematic review. *Journal of Education and Health Promotion*, 7(1), 98. https://doi.org/10.4103/jehp.jehp_31_18
- German, J.D., Redi, A.A.N.P., Ong, A.K.S., Prasetyo, Y.T., & Sumera, V.L.M. (2022). Predicting factors affecting preparedness of volcanic eruption for a sustainable community: A case study in the Philippines. *Sustainability*, 14(18), 11329. <https://doi.org/10.3390/su141811329>
- Kurata, Y.B., Prasetyo, Y.T., Ong, A.K.S., Nadlifatin, R., Persada, S.F., Chuenyindee, T., & Cahigas, M.M.L. (2022). Determining factors affecting preparedness beliefs among Filipinos on Taal Volcano eruption in Luzon, Philippines. *International Journal of Disaster Risk Reduction*, 76, 103035. <https://doi.org/10.1016/j.ijdrr.2022.103035>
- Department of Education (DepEd). (2018). *Statement on the Philippines' ranking in the 2018 PISA results*. <https://www.deped.gov.ph/2019/12/04/statement-on-the-philippines-ranking-in-the-2018-pisa-results/>
- Cahyana, U., Supatmi, S., Erdawati, & Rahmawati, Y. (2019). The influence of web-based learning and learning independence toward student's scientific literacy in chemistry course. *International Journal of Instruction*, 12(4), 655–668. <https://doi.org/10.29333/iji.2019.12442a>
- Degorio, J.M.L., & Langub, M.K.C. (2025). Enhancing physics education through comic strips: A development research study. *International Journal of Instruction*, 18(2), 637–652. <https://doi.org/10.29333/iji.2025.18234a>
- Dacumos, L.P.N. (2016). Perspective of secondary teachers in the utilization of science Strategic Intervention Material (SIM) in increasing learning proficiency of students in science education. *AsTEN Journal of Teacher Education*, 1(2). <https://doi.org/10.56278/asten.v1i2.293>

- Gabucan, J.R., & Sanchez, J.M.P. (2021). Strategic Intervention Material (SIM)-based instruction in teaching global warming in 9th grade science. *Formatif: Jurnal Ilmiah Pendidikan*, 11(1), 15–24. <https://doi.org/10.30998/formatif.v11i1.6448>
- Borabo, J.G., & Dio, R.V. (2025). Effectiveness of Strategic Intervention Material (SIM) in improving Filipino students' performance in science and mathematics: A meta-analysis. *Journal of Basic Education Research*, 6(2), 79–89. <https://doi.org/10.51405/jber.v6i2.1420>
- Mayer, R.E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
- Bruner, J. (1990). *Acts of meaning*. Harvard University Press.
- Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Fitria, Y., Malik, A., Halili, S.H., & Amelia, R. (2023). Digital comic teaching materials: Its role to enhance student's literacy on organism characteristic topic. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(10), em2333. <https://doi.org/10.29333/ejmste/13573>
- Hosler, J., & Boomer, K.B. (2011). Are comic books an effective way to engage nonmajors in learning and appreciating science? *CBE Life Sciences Education*, 10(3), 309–317. <https://doi.org/10.1187/cbe.10-07-0090>
- Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication*, 8(4), A02. <https://doi.org/10.22323/2.08040202>
- Molina, J.T., & Cadorna, E.A. (2025). Enhancing Filipino students' learning outcomes in physics using comic-based learning materials. *International Journal of Learning, Teaching and Educational Research*, 24(11), 185–204. <https://doi.org/10.26803/ijlter.24.11.9>
- Samosa, R.C. (2021). CoSIM (comics cum SIM): An innovative material in teaching biology. *European Journal of Research Development and Sustainability*, 2(4), 19–28. <https://files.eric.ed.gov/fulltext/ED618190.pdf>
- OECD. (2023). *PISA 2022 assessment and analytical framework*. OECD Publishing. <https://doi.org/10.1787/dfe0bf9c-en>
- Valio, F.A., Safira, L., Aulliyah, U.A., & Suwarna, I.P. (2025). Development of a science literacy test for junior high school students based on the PISA 2025 framework. *Jurnal Pendidikan MIPA*, 26(3), 1377–1405. <https://doi.org/10.23960/jpmipa.v26i3.pp1377-1405>
- Eisner, W. (2008). *Comics and sequential art: Principles and practices from the legendary cartoonist*. WW Norton & Company.
- Rasmet, R.R., Shaafi, N.F., Sharif, S., Nasir, S.M., Salleh, M.F.M., & Ellianawati, E. (2025). The impacts of comic-based learning on student engagement in primary education: A systematic literature review. *Citra Journal of Innovative Education Practices*, 1(1), 26–39. <https://doi.org/10.37934/cjiep.1.1.2639>
- Fananta, M.R., Umbara, T., & Valdez, N.P. (2019). The effect of inquiry-based science comics on primary learners' scientific literacy skills. *Global Journal of Business and Social Science Review*, 7(4), 210–216. [https://doi.org/10.35609/gjbssr.2019.7.4\(1\)](https://doi.org/10.35609/gjbssr.2019.7.4(1))
- Rosidah, C.T., Putrayasa, I.B., Wesnawa, I.G.A., & Candiasa, I.M. (2022). Thematic comic to cultivate eco-literacy for young learners. *Kasetsart Journal of Social Sciences*, 43(3), 735–740. <https://doi.org/10.34044/j.kjss.2022.43.3.27>
- Valente, B., & Faria, C. (2026). Turning the page on a missed opportunity: Science comics through the eyes of future elementary teachers. *Journal of Education*. <https://doi.org/10.1177/00220574261428474>
- Lituañas, A.B., & Dela Cruz, F.M. (2024). Development and validation of contextualized strategic intervention materials in science for Grade 6 learners. *Randwick International of Education and Linguistics Science Journal*, 5(4), 1363–1383. <https://doi.org/10.47175/rielsj.v5i4.1103>
- Branch, R.M., & Varank, İ. (2009). *Instructional design: The ADDIE approach*. Springer.
- Gall, M.D., Borg, W.R., & Gall, J.P. (1996). *Educational research: An introduction*. Longman Publishing.
- Francek, M. (2013). A compilation and review of over 500 geoscience misconceptions. *International Journal of Science Education*, 35(1), 31–64. <https://doi.org/10.1080/09500693.2012.736644>
- King, C. (2010). An analysis of misconceptions in science textbooks: Earth science in England and Wales. *International Journal of Science Education*, 32(5), 565–601. <https://doi.org/10.1080/09500690902721681>
- Demirci, T., & Okur, S. (2021). The effect of teaching science through storytelling on students' academic achievement, story writing skills and opinions about practice. *Education Quarterly Reviews*, 4(2), 562–578. <https://doi.org/10.31014/aior.1993.04.02.301>
- Korur, F., Erduran Avci, D., & Gürkan, Ş. (2025). Comparison of the effects of stories and digital stories containing refutation texts on conceptual understanding and correction of misconceptions in primary science education. *SAGE Open*, 15(4), 1–19. <https://doi.org/10.1177/21582440251403736>
- Fleiss, J.L. (1971). Measuring nominal scale agreement among many raters. *Psychological Bulletin*, 76(5), 378–382. <https://doi.org/10.1037/h0031619>
- Landis, J.R., & Koch, G.G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159–174. <https://doi.org/10.2307/2529310>
- The jamovi project. (2022). *Jamovi* (Version 2.4) [Computer software]. <https://www.jamovi.org>
- Feinstein, A.R., & Cicchetti, D.V. (1990). High agreement but low Kappa: I. The problems of two paradoxes. *Journal of Clinical Epidemiology*, 43(6), 543–549. [https://doi.org/10.1016/0895-4356\(90\)90158-L](https://doi.org/10.1016/0895-4356(90)90158-L)
- McHugh, M.L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica*, 22(3), 276–282. <https://doi.org/10.11613/BM.2012.031>
- Rosana, D., Widodo, E., Setyaningsih, W., & Setyawarno, D. (2020). Developing assessment instruments of PISA model to measure students' problem-solving skills and scientific literacy in junior high schools. *Jurnal Pendidikan Sains Indonesia*, 8(2), 292–305. <https://doi.org/10.24815/jpsi.v8i2.17468>
- Renouard, A., & Mazabraud, Y. (2018). Context-based learning for Inhibition of alternative conceptions: The next step forward in science education. *Npj Science of Learning*, 3(1), 10. <https://doi.org/10.1038/s41539-018-0026-9>

Розроблення та валідація КомікСІМ з теми вулканічної активності з інструментом оцінювання, узгодженим із ПІЗА

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 10 с., 5 табл., 2 рис., 38 джерел.

Мета. Навчальні матеріали на основі коміксів демонструють вимірюване підвищення залученості учнів і рівня природничо-наукової грамотності; проте лише в небагатьох дослідженнях формат коміксів інтегрується зі стратегічними інтервенційними матеріалами (SIM) та оцінюванням, узгодженим із PISA, у викладанні наук про Землю в середніх школах Філіппін. У цьому дослідженні було розроблено та валідовано ComicSIM — стратегічний інтервенційний матеріал у форматі коміксу з теми вулканічної активності для природничих наук у 9 класі, а також узгоджений із PISA інструмент оцінювання, що містить 20 завдань за вісьмома уроками.

Матеріали та методи. Використано описово-розробницький дизайн дослідження. П'ять експертів, які мали наукові ступені у галузі природничо-наукової освіти або розроблення навчальних програм і щонайменше п'ять років професійного досвіду, незалежно оцінювали обидва інструменти. ComicSIM оцінювали за сімома підкритеріями з використанням 5-бальної шкали; узгодженість оцінок експертів визначали за допомогою каппи Флейса. Інструмент оцінювання, узгоджений із PISA, оцінювали за 15-пунктовим інструментом відповідності з використанням 4-бальної шкали; внутрішню узгодженість визначали за допомогою альфи Кронбаха.

Результати. ComicSIM отримав середньозважену оцінку 4,5 («відмінно») та значення каппи Флейса 0,70 (суттєва узгодженість). Інструмент оцінювання, узгоджений із PISA, мав середню оцінку відповідності 3,8 («повністю згоден»), середню оцінку за вимірами 4,93 («відмінно») та значення каппи 0,87 (майже повна узгодженість). Значення альфи Кронбаха 0,88 підтвердило високу внутрішню узгодженість.

Висновки. Обидва інструменти пройшли експертну валідацію, є надійними та придатними для використання з метою розвитку природничо-наукової грамотності, узгодженої з PISA, у викладанні природничих наук у середніх школах Філіппін; водночас їхня ефективність у класі потребує підтвердження подальшими емпіричними дослідженнями.

Ключові слова: ComicSIM, стратегічний інтервенційний матеріал, PISA, вулканічна активність, природничі науки у 9 класі.

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