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Development of Comic-Assisted Interactive Media to Improve Learning Outcomes on Lithosphere Material in Grade X Geography: A Contribution to Quality Education (SDG 4)

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Abstract: Lithosphere processes are difficult to observe directly, while teacher-centered instruction and static media limit students' conceptual understanding. This study developed comic-assisted interactive media for Grade X geography and evaluated its validity, practicality, and effectiveness. Research and development followed the ADDIE model. The product was created with Lumi Education as an H5P Interactive Book that integrated sequential comics, interactive videos, image hotspots, and quizzes with immediate feedback. Three experts assessed validity; one geography teacher and students evaluated practicality in small-group and whole-class trials; and 36 students participated in a one-group pretest-posttest evaluation. The media was highly valid for material (95.00%), media design (100.00%), and language (98.00%). Practicality was also high for the teacher (98.00%) and students in both the small-group and whole-class trials (97.00%). The mean score increased from 60.67 to 89.63; the Wilcoxon signed-rank test indicated a significant paired difference ($p < .001$), and the mean normalized gain was 0.73 (high). These findings indicate that the media is valid, practical, and potentially effective for supporting visualization, self-assessment, and teacher-facilitated discussion of lithosphere concepts.

Keywords: Comic-assisted media; Geography education; H5P Interactive book; Learning outcomes; Lithosphere

Introduction

Digitalization has made technology-supported learning an increasingly important route to twenty-first-century competencies and to Sustainable Development Goal 4, especially equitable access to effective secondary education. Meta-analytic evidence indicates that technology can improve achievement when it is integrated with purposeful pedagogy rather than added as decoration (Tamim et al., 2011; Sung et al., 2016; Hillmayr et al., 2020). For geography education, this means using digital tools to make complex spatial and temporal processes observable, manipulable, and open to formative feedback.

Lithosphere topics are especially demanding because plate movement, volcanism, seismic processes, and landform development occur below the surface or across scales that students cannot observe directly. In West Sumatra, these concepts are also connected to everyday hazard awareness because communities live near active faults and volcanoes. Contextual, interactive visualization can therefore support both conceptual understanding and disaster-mitigation literacy, as shown by geography-media studies on volcanic environments and H5P-based atmospheric learning (Nursa'ban et al., 2022; Matana et al., 2024).

The preliminary study at SMA Negeri 1 Lubuk Alung showed that instruction remained dominated by lectures, static slides, and text-heavy worksheets. Observation and interviews indicated limited questioning and discussion, while daily-test data showed that approximately 55% of the 36 Grade X

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students had not met the learning-objective criteria. The greatest difficulties concerned analysis and application of plate subduction, volcano formation, and seismic activity rather than factual recall. These conditions made a visual, interactive, and classroom-ready learning medium necessary.

The learners are more accurately described as digitally immersed adolescents than assigned to a single generational label. They were accustomed to smartphones, visual content, flexible navigation, and rapid feedback, yet these preferences did not automatically produce deep learning. Research on mobile and interactive learning emphasizes that access must be paired with structured tasks, clear guidance, and active engagement (Sung et al., 2016; Rahmi et al., 2024; Jacob & Centofanti, 2024). Accordingly, learner characteristics guided the interface and interaction design without treating technology familiarity as equivalent to conceptual mastery.

The design combined individual cognitive support with classroom social interaction. Multimedia principles explain how coordinated words, pictures, animation, and learner control can reduce unnecessary cognitive load and help students build coherent mental models (Mayer & Moreno, 2003; Höffler & Leutner, 2007; Fiorella & Mayer, 2018). Social constructivism was applied through teacher-facilitated peer discussion after students explored the media, not through fictional comic dialogue alone. The interactive book supplied visualization and formative feedback, while the teacher used the resulting classroom time for questioning, comparison of explanations, and collaborative reasoning (Vygotsky, 1978; Freeman et al., 2014; Ting et al., 2023).

Educational comics can translate abstract science into a sequential visual narrative, whereas interactive media can add embedded questions, immediate feedback, and self-paced review. International studies report benefits of science comics for engagement and conceptual access (Tatalovic, 2009; Spiegel et al., 2013; Lin et al., 2015; Reumont & Budke, 2023), while Indonesian research has documented the validity or effectiveness of digital comics across science topics (Aisyah & Setiawan, 2023; Amali et al., 2023; Fatimah & Fatonah, 2023; Kartika et al., 2023; Khaira et al., 2020; Maulidah & Wulandari, 2021; Mutiaramses & Fitria, 2022; Novelita et al., 2024; Rahayuningsih & Setiawan, 2023; Utamingsih et al., 2023). These studies show that combining comics and digital media in general is not itself new.

The specific contribution of this study is a lithosphere-focused H5P Interactive Book produced in Lumi Education that integrates a continuous comic storyline, interactive videos, image hotspots, instant-feedback quizzes, and locally relevant hazard contexts in one web-accessible product. This combination addresses the visualization demands of geological processes while connecting independent exploration to teacher-facilitated discussion. The study therefore aimed to document the ADDIE development process and determine the media's validity, practicality, and potential effectiveness for improving Grade X geography learning outcomes.

Method

Research Type and Model

This study used a Research and Development design to produce and evaluate comic-assisted interactive media. Development followed the ADDIE model - Analysis, Design, Development, Implementation, and Evaluation - because its iterative structure supports systematic needs assessment, prototype construction, expert review, user trials, and revision (Branch, 2009).

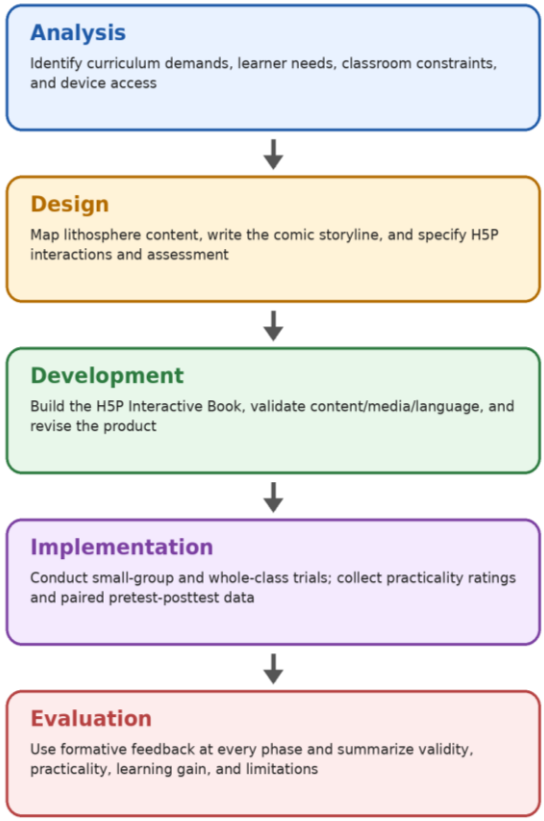

Figure 1. Operational ADDIE flow in this study

During analysis, interviews, observations, student questionnaires, curriculum review, and device-access checks defined the learning problem. Design translated these findings into a content map, comic storyline, visual system, navigation structure, H5P activities, and assessment plan. Development assembled the Interactive Book, obtained material, media, and language validation, and revised the prototype.

Implementation comprised a small-group trial followed by a whole-class trial and a one-group pretest-posttest evaluation. Evaluation was formative at every phase and summative when validity, practicality, and learning outcomes were synthesized.

Subjects, Data, and Instruments

Participants comprised three expert validators one each for geography content, instructional media, and language one geography teacher, and 36 Grade X students at SMA Negeri 1 Lubuk Alung. The field study was conducted from April to May 2026. Qualitative data consisted of validator, teacher, and student comments; quantitative data consisted of validation ratings, practicality ratings, and paired pretest-posttest scores. Instruments included interview and observation guides, expert-validation sheets, teacher and student practicality questionnaires, and a learning-outcome test. Closed questionnaire items used a five-point Likert scale, while open responses documented revision needs. Table 1 summarizes the instruments.

Table 1. Research instruments and structure

Instrument	Assessed aspects	Items
Material validation	Suitability, depth, accuracy, relevance, currency, examples	20
Media validation	Media design, comic design, content presentation	20
Language validation	Clarity, correctness, terminology, effectiveness, instructions	20
Teacher practicality	Effectiveness, ease of use, supporting features	20
Student practicality	Effectiveness, ease of use, supporting features	20

Data Analysis

Validity and practicality scores were divided by the maximum attainable score and multiplied by 100.00. The resulting percentages were interpreted with the five-category rubric in Table 2. Qualitative feedback was coded by source and design component, then used to document the revisions made before implementation.

Table 2. Validity and practicality criteria

Percentage (%)	Validity	Practicality
81.00-100.00	Highly valid	Highly practical
61.00-80.00	Valid	Practical
41.00-60.00	Fairly valid	Fairly practical
21.00-40.00	Less valid	Not practical
0.00-20.00	Invalid	Highly impractical

Source: Adapted from Riduwan (2012)

Potential effectiveness was examined with a pre-experimental one-group pretest-posttest design involving the same 36 students at both measurement points (Shadish et al., 2002). Because the observations were paired, inferential analysis focused on the distribution of within-student difference scores. The normality assumption was not met; therefore, the Wilcoxon signed-rank test for related samples was used (Wilcoxon, 1945). Improvement magnitude was summarized with normalized gain, g = (posttest - pretest)/(maximum score - pretest), and interpreted as high ($g > 0.70$), moderate ($0.30 <= g <= 0.70$), or low ($g < 0.30$) following Hake (1998).

Result and Discussion

Analysis Phase

The needs analysis aligned the teacher's concerns with the students' reported difficulties. Interviews showed that the main obstacle was not terminology alone but constructing meaning for tectonism, volcanism, and seismic processes that cannot be observed directly. Observation confirmed a teacher-centered classroom: few students asked questions, attention declined after approximately 20-30 minutes, and most activity consisted of copying notes. The teacher consequently prioritized mobile access, a narrative that prompts reasoning, and self-assessment with immediate feedback.

Student questionnaires reinforced this diagnosis. More than 70% of respondents preferred visual-spatial representations, and almost all had smartphones capable of accessing the proposed web product. Students also valued examples connected to hazards in West Sumatra. Curriculum analysis then mapped these needs to Phase E outcomes on identifying, explaining, and analyzing lithosphere dynamics and their effects on human life. Together, the needs, learner, resource, and curriculum analyses justified a visual-interactive design while avoiding the assumption that digital familiarity alone guarantees learning.

Design and Development Phase

In the design phase, the needs were translated into an H5P Interactive Book in Lumi Education. A side-menu table of contents enabled access to tectonism, volcanism, seismic processes, and exogenic forces, while next/previous controls preserved the comic's narrative sequence. Interactive checkpoints were placed after each subtopic. The interface used an earth-tone palette, readable typography, and a responsive layout for smartphones and laptops.

The storyline progressed through scientific missions in which a student protagonist posed questions and a mentor clarified difficult concepts. Multiple-choice quizzes gave immediate explanatory feedback and redirected incorrect responses to the relevant panel; interactive videos paused for embedded questions; and image hotspots revealed labels without overcrowding

the illustrations. These design choices were intended to coordinate visual explanation, learner control, and retrieval practice rather than add interaction for its own sake.

During development, text, illustrations, videos, hotspots, and quiz items were assembled and exported as a self-contained HTML5 product accessible by link or QR code without requiring students to install Lumi. The validity and practicality instruments were first reviewed by an educational-evaluation expert and each received 92.00%, categorized as highly valid. The product then proceeded to content, media, and language validation before classroom use.

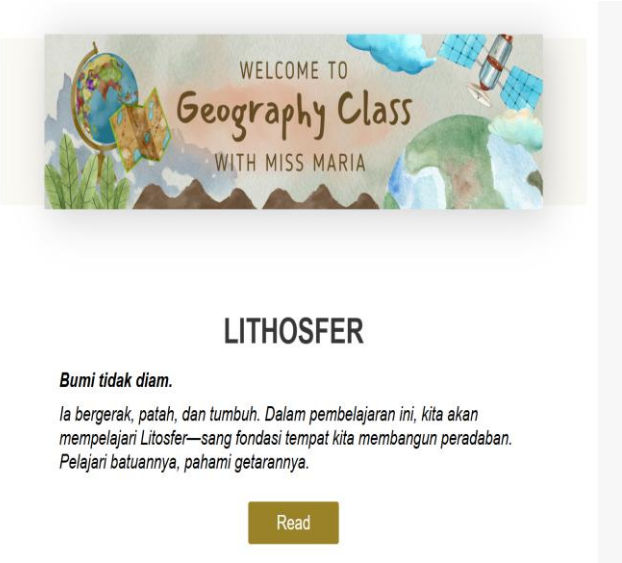

Figure 2. Home page

Figure 3. Introduction

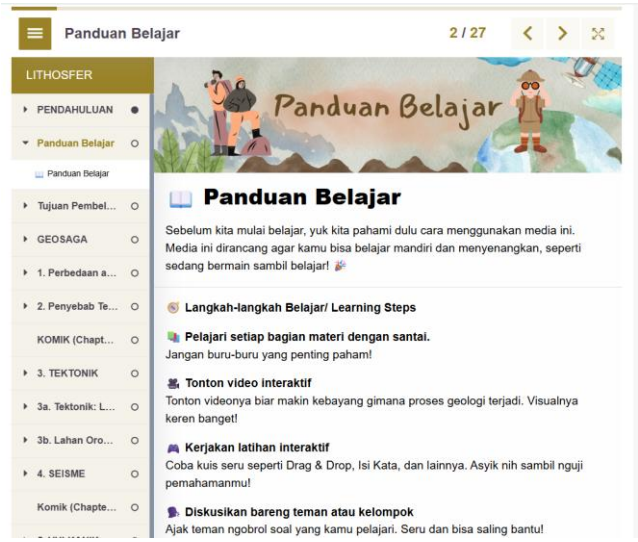

Figure 4. Study guide

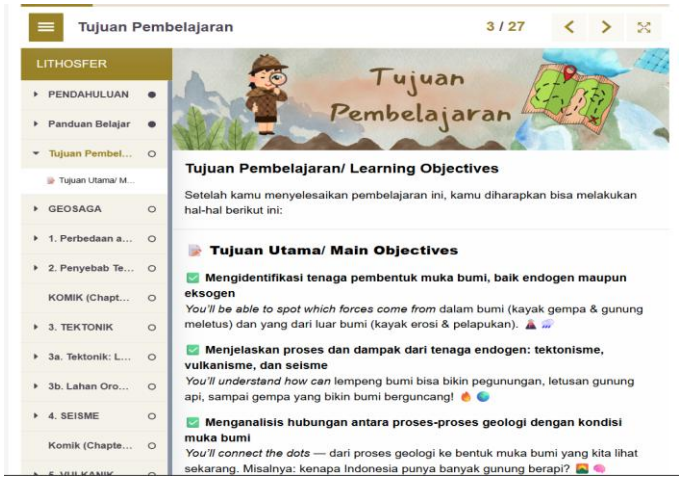

Figure 5. Learning objectives

Figure 6. Learning materials

Figure 7. Comic education

Figure 8. Exercise

Validity of the Media

The completed product was then validated by three experts, with material validation by a geography content specialist, media validation by an instructional-media specialist, and language validation by a language specialist. The material validation results by aspect are presented in Table 3, and the overall recapitulation across the three areas in Table 4.

Table 3. Material validation by aspect

Aspect	Percentage (%)	Category
Material suitability	100.00	Highly valid
Material depth	95.00	Highly valid
Material accuracy	100.00	Highly valid
Material relevance	93.00	Highly valid
Material currency	87.00	Highly valid
Examples and items	93.00	Highly valid

Table 4. Validity assessment

Aspect	Percentage (%)	Category
Material	95.00	Highly valid
Media	100.00	Highly valid
Language	98.00	Highly valid

Expert validation placed the product in the highly valid category for material, media, and language. Material suitability and accuracy each reached 100.00%, indicating alignment with Phase E outcomes and the absence of identified conceptual errors. Material depth reached 95.00%, suggesting that the comic format did not require reducing the topic to superficial facts. Material currency was the lowest score at 87.00%, which identified a specific need to strengthen recent examples and sources rather than a general design weakness.

The revision record made the development process more transparent. Recent disaster examples and updated learning sources were added to the relevant panels; question sets were reorganized to include basic comprehension, application, and higher-order items; crowded labels were enlarged; and typographical errors were corrected. The revised version was returned to the validators before implementation. The final media and language scores of 100.00% and 98.00%, respectively, supported the functionality and communicative clarity of the product.

Practicality of the Media

After revision, the validated product entered the implementation phase, in which practicality was assessed from the perspectives of both the teacher and the students. The recapitulation is presented in Table 5.

Table 5. Practicality assessment

Respondent	Percentage (%)	Category
Teacher	98.00	Highly practical
Students (small group)	97.00	Highly practical
Students (whole class)	97.00	Highly practical

The teacher response averaged 98.00% (highly practical), with 100.00% for effectiveness, 98.00% for ease of use, and 97.00% for supporting features. Student practicality was 97.00% in the small-group trial and remained 97.00% in the whole-class trial with 36 students; these are separate trial results, not a combined percentage. The stable ratings indicated that navigation, access, and feedback remained usable when the product was scaled to the full class. The teacher also reported that individual visualization and self-assessment reduced the time needed for extended explanation and created more room for comparison, questioning, and group discussion.

Effectiveness of the Media

Potential effectiveness was evaluated with paired pretest and posttest scores from the same 36 students

across three meetings. Because the within-student difference scores did not meet the normality assumption, the Wilcoxon signed-rank test was applied. Table 6 presents the descriptive results, paired-test significance, and normalized gain.

Table 6. Effectiveness results

Parameter	Result
Number of students	36
Mean pretest score	60.67
Mean posttest score	89.63
Wilcoxon signed-rank (p)	< .001
Mean normalized gain	0.73 (high)

The mean score increased from 60.67 to 89.63. The Wilcoxon signed-rank test indicated a statistically significant paired difference ($p < .001$), and the mean normalized gain was 0.73, categorized as high. These results show a substantial improvement during the intervention; however, because the design did not include a control group, the change should be interpreted as evidence of potential effectiveness rather than as an isolated causal effect of the media.

Discussion

The validity results are consistent with Indonesian digital-comic studies reporting strong feasibility when visual narrative is aligned with curriculum, readable interfaces, and structured learning tasks (Puriasih et al., 2022; Ramadanti & Bektiningsih, 2023; Suwandinata & Suranata, 2023; Fitriyanti et al., 2023). Similar studies have found that comics can support scientific literacy, motivation, or learning outcomes across different topics (Amali et al., 2023; Mutiaramses & Fitria, 2022; Utamingsih et al., 2023; Fitria et al., 2023; Mirosunnaily & Pramudiani, 2021). The present study extends that pattern to lithosphere concepts and adds a documented revision pathway from expert comments to the implemented product.

The stable practicality rating across the small-group and whole-class trials suggests that the medium remained usable beyond initial prototype testing. This result aligns with national studies in which interactive digital comics improved engagement and independent access (Khotimah & Hidayat, 2022; Fahreza et al., 2022; Sari et al., 2022b; Bella et al., 2024). It also agrees with multimedia and H5P studies reporting positive perceptions, satisfaction, or learning support when interactive content is pedagogically integrated (Suryanti et al., 2021; Utari et al., 2022; Matana et al., 2024; Rahmi et al., 2024). At the same time, Jacob & Centofanti (2024) found positive student perceptions but no clear achievement advantage when engagement with H5P resources was low. That mixed evidence supports the present study's emphasis on teacher guidance, required checkpoints, and in-class follow-up rather than assuming that the platform alone produces learning.

The high normalized gain and significant Wilcoxon result are compatible with meta-analytic evidence that well-designed digital tools can improve mathematics and science learning (Tamim et al., 2011; Sung et al., 2016; Hillmayr et al., 2020; Merchant et al., 2014) and with studies showing that dynamic visualization is most useful when it depicts processes that are otherwise difficult to observe (Höffler & Leutner, 2007). The result also parallels digital-comic studies that reported gains in science achievement or engagement (Aisyah & Setiawan, 2023; Khaira et al., 2020; Rahayuningsih & Setiawan, 2023; Tristaningrat & Ariyana, 2025). Nevertheless, the paired one-group design warrants a cautious claim: the evidence supports improvement associated with the intervention, not superiority over another method.

The theoretical contribution is a clearer division of labor between cognitive and social mechanisms. The comic sequence, interactive video, hotspots, and feedback support individual selection, organization, and integration of words and images, consistent with multimedia-learning research (Mayer & Moreno, 2003; Fiorella & Mayer, 2018). Social constructivism occurs when the teacher uses the time released from extended lecturing to organize peer explanation, question competing interpretations, and scaffold analysis of local hazards (Vygotsky, 1978). This interpretation accords with evidence that active learning and discussion outperform passive reception when learners must reason with scientific ideas (Freeman et al., 2014; Ting et al., 2023).

The visual-narrative component also helps explain why an interactive book is suited to lithosphere learning. Science comics can make unfamiliar mechanisms more approachable by linking technical language to characters, sequences, and concrete situations (Tatalovic, 2009; Spiegel et al., 2013; Lin et al., 2015). However, comics are not automatically accurate or cognitively efficient. The expert-validation and revision stages were therefore essential for checking scientific representations, controlling visual density, and ensuring that interaction focused attention on causal processes. This design logic is supported by Indonesian reviews and development studies emphasizing curriculum alignment and careful media validation (Nandasari & Mufti, 2024; Anggraeni et al., 2023; Kusmajid et al., 2024; Sari et al., 2022a).

The study has three main limitations. First, the one-group pretest-posttest design cannot rule out testing, maturation, or history effects. Second, the participants came from one school, limiting generalizability. Third, the evaluation covered short-term learning outcomes and did not measure retention, transfer, or changes in

disaster-response behavior. Future studies should use a control group, retain student-level paired data for transparent Wilcoxon reporting and effect-size calculation, involve multiple schools, add delayed tests, and examine how teacher-facilitated discussion contributes beyond self-paced media use. Research photographs and implementation logs should also be archived prospectively to strengthen evidence of the classroom process.

Conclusion

This study developed a Lumi Education H5P Interactive Book that combines a sequential lithosphere comic with interactive video, image hotspots, and immediate-feedback quizzes. The product was highly valid for material (95.00%), media design (100.00%), and language (98.00%), and highly practical for the teacher (98.00%) and students in both small-group and whole-class trials (97.00%). Paired scores increased from 60.67 to 89.63, with a significant Wilcoxon signed-rank result ($p < .001$) and a high mean normalized gain of 0.73. The findings support the media's use for visualization, self-assessment, and teacher-facilitated discussion, while the one-group design limits causal inference. Future research should use control groups, multiple schools, delayed retention measures, and complete implementation documentation.

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Author Contributions
Conceptualization, M.M. and Z.Z.; methodology, M.M., Z.Z., A.H., and U.R.; software, formal analysis, investigation, resources, data curation, writing - original draft, M.M.; validation, A.H. and U.R.; writing - review and editing, Z.Z., A.H., and U.R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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