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Implementing Remote Sensing Teaching Materials Through Digital Literacy to Support Flood Risk Reduction Education

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ABSTRACT

Geography education can connect remotely sensed imagery with local environmental problems and provide opportunities to develop students' understanding of flood risk. This study describes the implementation of remote sensing teaching materials supported by digital information access in class XII IPS 1 at SMAN 1 Pangkep, South Sulawesi, Indonesia. A descriptive qualitative approach was used, with classroom observations, student worksheets, and a graphical display of learning results supporting the account. Students worked in five heterogeneous groups to analyze possible causes of local flooding, mark potentially flood-prone locations on printed imagery, and present their findings. The teacher obtained imagery from Google Maps and supplied worksheets containing photographs of locations affected by a previous flood. Smartphones supported information searching, while image annotation was completed manually using red markers. The source manuscript reported final cognitive achievement scores ranging from 77 to 92 and stated that all students exceeded the school's minimum mastery benchmark. The teacher also described improved participation and students' ability to relate marked image locations to recognizable ground features. Students identified sedimentation, waste accumulation, drainage limitations, and settlement patterns as issues for discussion and proposed actions involving learners, residents, and local government. Limited geography laboratory facilities and disaster-related literature constrained implementation. The findings illustrate a feasible combination of digital resources and printed materials for contextual geography learning. However, missing individual numerical records, unspecified assessment procedures, and the absence of hydrological validation prevent conclusions about a causal learning effect, mapping accuracy, or an actual reduction in flood risk.

Keywords: remote sensing; digital literacy; geography education; flood risk reduction; spatial interpretation

INTRODUCTION

Flood risk provides a relevant context for teaching the relationships between environmental processes, land use, settlement, and human vulnerability. Satellite observations can reveal flood extent and exposure, while research on flood exposure and poverty shows why identifying affected places also requires attention to social conditions (Rentschler et al., 2022; Tellman et al., 2021). Evidence from the United States similarly illustrates that flood risk is unevenly distributed, although those national findings cannot be transferred directly to Pangkep (Wing et al., 2022). Geography lessons can use these wider perspectives to help students distinguish the physical

occurrence of flooding from the consequences for people and communities.

Schools have an important role in building understanding of natural hazards and preparedness. Reviews of school-based education programs and disaster preparedness resources identify a range of educational approaches while also highlighting limitations in their design and evaluation (Hodson et al., 2024; Seddighi et al., 2022). A more recent synthesis of disaster risk reduction education reviews reinforces the need to examine what children learn and how educational experiences relate to action (Lownsbery, 2025). Learning about flood risk should therefore involve more than memorizing hazard terminology; it should help students interpret information and explain the environmental conditions discussed in their own locality.

Remote sensing provides one way to make this learning spatially concrete. Images allow students to examine the relative positions of rivers, roads, settlements, and other visible features. Research on Earth observation for flood modeling describes the technical contribution of remotely sensed information (Schumann et al., 2023), while a review of urban flood applications documents varied uses and research gaps (Zhu et al., 2022). Classroom image interpretation draws on this information resource, but it differs substantially from professional flood modeling and validated susceptibility mapping.

Digital literacy is relevant because students and teachers must locate, interpret, and communicate information obtained through digital resources. Reviews of digital literacy and its educational factors describe a broader set of abilities than operating a device alone (Audrin & Audrin, 2022; Tinmaz et al., 2022). Within geography, inquiry supported by geospatial technologies can link digital competencies with topic knowledge (Mašterová, 2023). Such opportunities depend on how resources are selected and integrated into learning activities, rather than simply on whether a smartphone or map platform is available.

At SMAN 1 Pangkep, remote sensing was regarded as a difficult geography topic, and the teacher initially observed limited student participation. The school lacked a dedicated geography laboratory and had limited disaster-related reading materials. The instructional response combined imagery obtained from Google Maps, printed student worksheets, smartphone-supported information searching, group discussion, and manual annotation. The local issue of flooding in Pangkep provided the problem around which these activities were organized.

This study aimed to describe how remote sensing teaching materials supported by digital literacy practices were implemented for flood risk reduction education. It focused on three activities: analyzing possible flood causes, marking potentially flood-prone locations on imagery,

and presenting group findings. It also examined the learning results reported by the teacher and the practical constraints encountered. Its contribution is a descriptive account of a classroom approach that combines digital resource access with paper-based spatial interpretation under limited facilities.

LITERATURE REVIEW

Remote Sensing, Flood Information, and Spatial Reasoning

Remote sensing involves obtaining information about the Earth's surface without direct contact with the features being observed. Image sources, acquisition dates, spatial resolution, and processing methods influence what can be interpreted. Reviews of advances in satellite flood observation and Earth observation-based flood modeling demonstrate that flood information depends on the properties of the data and the methods used (Schumann et al., 2023; Schumann, 2024). These principles are relevant to teaching students that an image is an information source with limitations, rather than an automatically accurate representation of flood risk.

Professional flood analysis may combine imagery with terrain, rainfall, river discharge, exposure, and other datasets. A review of urban flood-related remote sensing identifies applications including detection, monitoring, risk assessment, and impact analysis (Zhu et al., 2022). The present classroom activity used visible features and photographs of previously affected places to guide marking on printed imagery. It did not use hydraulic models, automated classification, or a validated flood inventory. Its principal educational value therefore concerns spatial interpretation and discussion rather than the production of an operational hazard map.

Spatial thinking requires learners to reason about location, relationships, scale, and representations. A systematic review in geoscience education argues for more opportunities to practice spatial thinking and examine the reasoning strategies students use (McLaughlin & Bailey, 2023). Research on geographical thinking provides a complementary perspective on the forms of reasoning developed through geography education (Bendl et al., 2025). Matching a photographed location to its representation on imagery offers a concrete classroom task through which students can discuss evidence for spatial correspondence.

Geospatial technologies can support such learning when they are integrated with suitable instruction. Research using a digital atlas in secondary education examines WebGIS as an instructional resource (De Miguel González & De Lázaro Torres, 2020), while a study of geospatial technology integration in geography lessons examines implementation through the

technological pedagogical content knowledge framework (Huh & Jo, 2023). Portfolio-based GIS learning in an upper secondary course provides another example of organizing progressively demanding geospatial activities and documenting student work (Anunti et al., 2020). These studies provide related pedagogical perspectives, but they should not be treated as evidence that the present students operated GIS software. The activity reported here involved information retrieval and manual annotation, with no student use of MapInfo or equivalent GIS analysis documented.

Digital Literacy and Instructional Design

Digital literacy includes the ability to work meaningfully with information and digital resources. Reviews identify multiple themes and factors associated with its development (Audrin & Audrin, 2022; Tinmaz et al., 2022). In this study, the relevant practices were locating supporting information, interpreting map imagery alongside photographs, and discussing findings. Device access enabled these activities, but the study did not separately assess students' digital literacy proficiency.

Teachers' digital competence also involves selecting resources and making instructional decisions. A teacher digital competency framework connects competence with educational practice (Falloon, 2020), while a review of digital competencies for professional development identifies an important role for teacher learning (Fernández-Batanero et al., 2022). Research on teachers' expertise and technology-enhanced lesson planning offers a further reason to attend to the quality of the task design (Backfisch et al., 2020). The teacher's worksheet can therefore be understood as an instructional structure connecting digital information with a geography objective.

The design of visual learning materials matters. Multimedia learning research considers how verbal and visual information is selected and presented (Noetel et al., 2022). Cognitive load theory offers a rationale for managing task complexity and information demands (Sweller, 2020), while evidence about seductive details cautions against adding appealing but irrelevant material (Sundararajan & Adesope, 2020). In an image interpretation lesson, these perspectives support clear prompts, relevant photographs, and explicit attention to the features students are expected to identify.

Active production can require learners to organize their understanding. Generative learning theory addresses the construction of meaningful representations (Fiorella, 2023), and research on age-related instructional conditions provides guidance for choosing such strategies (Brod, 2021). However, performing an activity is not sufficient evidence that learning has occurred

(Skulmowski, 2024). The worksheet annotations and presentations in this study need to be interpreted alongside the reported assessment results and the limitations of the available evidence.

Disaster Risk Reduction Education and Participation

Disaster risk reduction education can connect hazard knowledge with preparedness, participation, and community concerns. Research linking this education with sustainable development goals emphasizes the relevance of children, families, and local communities (Cabello et al., 2021). A review of school-based disaster risk reduction strategies in India also illustrates the range of school initiatives, although its national context differs from Indonesia (Goswami & Ahmad, 2025). These perspectives support using local flood problems as educational contexts while distinguishing proposed actions from actions that have been carried out and evaluated.

Participation should be meaningful and accessible. Research on children's participation through play identifies the importance of the process through which children influence decisions (Le Dé et al., 2021). Studies concerning inclusive disaster risk reduction education and disaster mitigation in Indonesian schools likewise consider participation, learning methods, and stakeholder involvement (Rofiah et al., 2021; Sheehy et al., 2024). The present study involved group discussion and presentation; it did not independently measure empowerment or evaluate the participation of learners with particular disabilities.

Environmental education research provides a wider context for examining knowledge, attitudes, intentions, and behavior. A meta-analysis distinguishes these outcomes in children and adolescents (van de Wetering et al., 2022). This distinction is important here: the students' suggestions about waste management and community cleanliness demonstrate ideas expressed in class, but they do not establish subsequent behavioral change or reduced flood losses.

Facilities, Resources, and Teacher Support

The integration of geospatial and digital resources is constrained by educational conditions. A systematic review of GIS implementation identifies limitations involving teachers and technology (Bernhäuserová et al., 2022). Reviews of teachers' technology use and perceptions likewise describe factors affecting classroom integration (Akram et al., 2022; Spiteri & Chang Rundgren, 2020). A printed-image approach may offer a practical route when a computer laboratory is unavailable, although it cannot provide all the functions of interactive geospatial analysis.

Teachers' roles in digitalizing education, the contextual factors associated with their digital competence, and the quality of integration frameworks are also relevant (Lucas et al., 2021; Tondeur et al., 2021; Wohlfart & Wagner, 2023). Research on professional development provides a further basis for considering sustained instructional support (Sims & Fletcher-Wood, 2021). The Indonesian source manuscript additionally draws on work about selecting and developing information technology-based instructional media (Zahwa & Syafi'i, 2022). These contributions frame the facility and resource constraints examined in the present classroom account.

METHODS

Design, Setting, and Participants

The source study used a descriptive qualitative approach, with a graphical data display supporting its account of classroom implementation. It was conducted in the geography learning context of class XII IPS 1 at SMAN 1 Pangkep, South Sulawesi, Indonesia. The teacher described students' learning activities and reported numerical achievement information. The study was not presented as an experiment or classroom action research with intervention cycles.

Participants were students in the designated Grade XII social sciences class. The source manuscript did not state the total class size, participant ages, selection procedures beyond identifying the class, or the dates and duration of implementation. Students were organized into five heterogeneous groups, considering differences in learning ability and access to resources such as smartphones. No participant characteristics beyond these classroom details are inferred in this report.

Materials and Learning Procedure

The teacher prepared student worksheets and obtained remotely sensed imagery from Google Maps. The worksheets included photographs of local places affected by a previous flood described in the source as occurring in February; the year was not specified. Smartphones supported searching for information about floods. Printed imagery and red markers were used for the annotation task. The imagery's sensor, acquisition date, resolution, and georeferencing details were not reported.

The first activity involved group analysis of possible causes of flooding in Pangkep. The discussion considered rainfall, watershed conditions, river channel development, sedimentation, and spatial planning or infrastructure. Students related these issues to the local river, drainage,

waste accumulation, and settlement patterns described in the learning materials and classroom discussion.

In the second activity, groups marked potentially flood-prone locations on the printed imagery using red rectangular symbols. They compared recognizable image features with photographs of previously affected places in the worksheets. The teacher regarded the correspondence between a marked location and the relevant ground feature as an important aspect of the practical task. No coordinate measurements, independently verified reference points, or formal accuracy statistics were reported.

In the third activity, groups presented their discussions and annotations. The source recorded the presentation order as Group 3, Group 5, Group 2, Group 4, and Group 1. The teacher observed the process and assessed learning during the activities. This procedure combined digital information access with manual work; the school did not provide a geography laboratory, and neither GIS software operation nor drone-based data collection was implemented.

Evidence and Descriptive Analysis

Evidence comprised teacher observations of learning activities, student work on the worksheets, and the achievement display included in the source manuscript. The observations addressed discussion, image annotation, presentation, cooperation, responsibility, curiosity, confidence, and motivation as described by the teacher. No standardized observation scale or separate validated measure of these characteristics was supplied.

The numerical result retained in this revision is the reported final score range of 77–92. The source states that all students exceeded the school's minimum mastery criterion, but does not give its numerical threshold. Its original chart displays bars labeled before and after the implementation, without printed individual score values or an accompanying numerical dataset. The chart is retained as supplied, with an English explanation of the original legend. Individual values, means, gains, effect sizes, and significance tests have not been reconstructed from bar heights.

Analysis followed the source's descriptive presentation: the learning sequence, classroom observations, reported achievement, student interpretations, and implementation constraints were organized for comparison and discussion. Tables in this revision summarize information explicitly stated in the source. No interviews, formal coding procedures, independent raters, test reliability estimates, or hydrological validation are claimed. These reporting limitations restrict conclusions about learning improvement and flood risk reduction.

RESULTS AND DISCUSSION

Implementation of the Learning Sequence

Students completed a three-part sequence connecting flood discussion with spatial interpretation and communication. Table 1 summarizes the activities and the evidence available in the manuscript. Grouping helped distribute access to information and enabled students to discuss recognizable local features. The worksheet linked the broad remote sensing topic with a specific problem concerning flooding in Pangkep.

Table 1. Instructional activities and reported classroom evidence

Activity	Materials and procedure	Reported evidence
Analyze flood causes	Five heterogeneous groups; worksheets and smartphone-supported information searches.	Discussion of rainfall, watershed conditions, river channel changes, sedimentation, drainage, and settlement.
Mark potentially flood-prone locations	Printed Google Maps imagery, photographs of previously affected locations, and red rectangular symbols.	Teacher-assessed correspondence between marked locations and recognizable ground features.
Present group findings	Presentations in the reported order: Groups 3, 5, 2, 4, and 1.	Group explanations, shared interpretations, and proposed stakeholder actions.

Source: Instructional procedure and teacher observations described in the original manuscript. The table organizes the reported activities; it does not add quantified participation measures.

During discussion, students considered several possible flood-related factors rather than interpreting the image in isolation. They then marked locations on the printed imagery and explained their reasoning during group presentations. The teacher reported that this arrangement encouraged participation in a topic that students had initially found difficult. These observations are descriptive; the manuscript does not provide counts or a standardized before-and-after participation score.

The approach is related to inquiry with geospatial resources because it connects questions about a place with the interpretation and communication of spatial information (Mašterová, 2023). The manual task also offers a context for practicing spatial correspondence, which is consistent with the need for repeated spatial reasoning opportunities identified in geoscience education (McLaughlin & Bailey, 2023). However, it does not establish mastery of a complete GIS workflow.

Reported Achievement and Practical Performance

The original achievement chart is reproduced in Figure 1. The source narrative reports final

scores from 77 to 92 and states that all students exceeded the school's mastery benchmark. The teacher described performance at the lower end of this range as moderate in cognitive and practical terms, whereas performance at the upper end was described as high, including appropriate correspondence between annotations and visible ground features. Table 2 separates these reported findings from information that was not supplied.

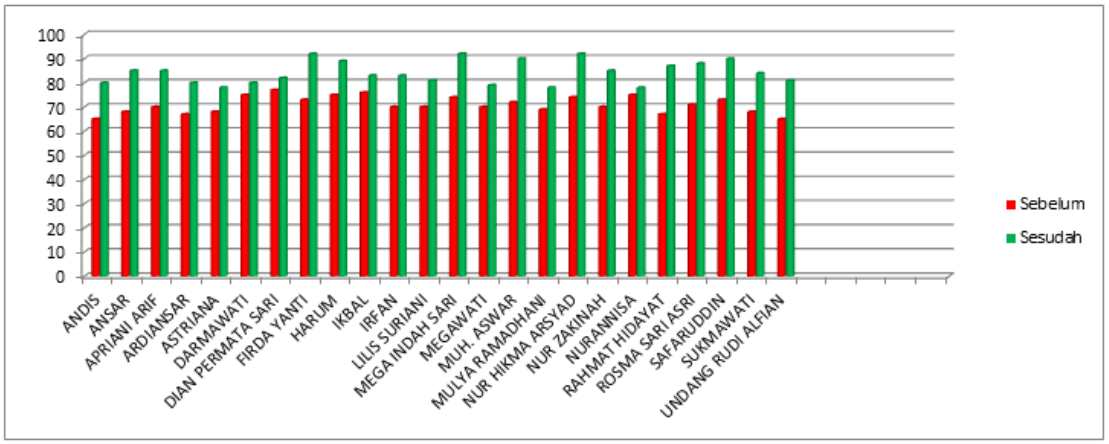


Figure 1. Original before-and-after achievement display supplied in the source manuscript.

Legend translation: red = before implementation (Sebelum); green = after implementation (Sesudah). The original chart and student labels are retained. Individual numerical values are not printed; bar heights have not been converted into numerical records.

Table 2. Reported learning outcomes and limits of the available evidence

Outcome	Information reported	Interpretation limit
Final achievement scores	Lowest: 77; highest: 92.	No complete individual dataset, mean, or component weighting was supplied.
Mastery	All students reportedly exceeded the school's minimum mastery benchmark.	The total class size and numerical benchmark were not stated.
Cognitive and practical performance	Teacher described moderate performance at 77 and high performance at 92; plotting correspondence was emphasized.	Rubric, scoring descriptors, and independent accuracy checks were not supplied.
Classroom participation	Teacher described greater activity, cooperation, responsibility, curiosity, confidence, and motivation.	No standardized observation scale or quantitative participation comparison was reported.

Source: Results narrative in the original manuscript. Statements are retained as teacher-reported findings; no new statistical or accuracy estimates have been calculated.

The chart indicates a visual before-and-after pattern, but exact individual values are unavailable. Consequently, it cannot support a recalculated mean gain or a statistical test. The source also does not specify whether the chart combines cognitive and practical performance or

how these components were weighted. The score range is therefore presented as reported achievement information, rather than as a newly derived quantitative evaluation.

The annotation task required students to connect a spatial representation with an identified place. This is a meaningful instructional demand, but the teacher's judgment that plotting was appropriate should not be described as a measured mapping accuracy rate. Professional flood mapping requires attention to data properties, methods, and validation (Schumann et al., 2023; Schumann, 2024). The classroom evidence demonstrates an image interpretation activity and the teacher's assessment of its products, with accuracy beyond that setting remaining unverified.

Students' Interpretations of Flooding in Pangkep

The classroom account situated Pangkep within a landscape involving coastal areas, lowland uses, and upland conditions. The source discussed paddy fields, aquaculture ponds, gardens, settlements, rivers, and drainage as part of the local context. These descriptions informed the lesson but were not accompanied by land cover measurements or a hydrological survey.

The groups emphasized river shallowing associated with sediment and waste accumulation. They also discussed drainage limitations, riverside settlement, and changes to riverbank structures. Rainfall and watershed conditions remained part of the broader discussion. Students' agreement about river shallowing is reported as a shared classroom interpretation, not as an independently established ranking of flood causes.

This distinction matters because flood occurrence and impact can arise from interacting physical and social conditions. Satellite research identifies flood extent and exposure at scales that differ from those used in the lesson (Tellman et al., 2021), while broader work on flood exposure and poverty illustrates why physical information alone does not describe social vulnerability (Rentschler et al., 2022). None of these studies verifies the causal explanations advanced for Pangkep in this classroom.

The source included recommendations concerning the relocation of a market, riverside settlement management, river maintenance, and vegetation. These are retained as issues raised in the local discussion. The study did not examine their technical feasibility, costs, consequences, or community acceptance. They should therefore be understood as topics for further investigation and stakeholder discussion, rather than as interventions demonstrated to reduce local flood risk.

Participation, Collaboration, and Digital Literacy

The teacher described students as more active in discussing flood causes, marking locations, and presenting their findings. Cooperation, responsibility, curiosity, confidence, and motivation were also observed during the group tasks. The account does not quantify these characteristics or distinguish individual contributions within each group. It supports a description of classroom participation rather than a validated measurement of character development or motivation.

The combination of image annotation and presentation may have encouraged learners to select information, organize explanations, and communicate their interpretation. Generative learning research provides a framework for considering these activities (Fiorella, 2023), but activity completion by itself does not demonstrate learning (Skulmowski, 2024). The teacher's observations and the reported achievement range provide complementary evidence, with neither eliminating the limitations of the other.

Digital literacy was embedded in the learning process through online information access and the use of digital imagery. It was not established by the possession of a smartphone, and it was not independently tested. A broader conception of digital literacy emphasizes the information work involved (Audrin & Audrin, 2022; Tinmaz et al., 2022). The present experience illustrates opportunities to practice those abilities, while the extent of proficiency gained remains unknown.

The role of instructional design is especially visible in this combination of digital and printed resources. The worksheet gave students a common task, relevant photographs, and a basis for discussion. Research on teacher expertise and technology-enhanced planning supports attention to this alignment (Backfisch et al., 2020), while multimedia design research offers a reason to make the relationship between visual information and learning prompts explicit (Noetel et al., 2022). These perspectives help interpret the teaching approach without claiming that a specific medium caused the results.

Proposed Environmental and Community Actions

Students proposed communicating environmental cleanliness messages, participating in community service, and supporting efforts to keep waterways free of waste. Suggestions for residents included maintaining drains, avoiding waste disposal into channels, and organizing regular neighborhood cleanliness activities. Suggestions for local government included public communication, river and drainage maintenance, vegetation management, and attention to

riverside settlement. The proposals are summarized as learning products; implementation and outcomes were not observed in the study.

Disaster risk reduction education can provide space for students to discuss community concerns and possible actions (Cabello et al., 2021; Le Dé et al., 2021). Indonesian research on inclusive disaster education further highlights the importance of meaningful participation and stakeholder involvement (Rofiah et al., 2021; Sheehy et al., 2024). The classroom findings here show students expressing ideas about different stakeholder roles, rather than demonstrate that they influenced local decisions.

Knowledge, intentions, and behavior should also be distinguished. Environmental education research examines these as different outcomes (van de Wetering et al., 2022). The proposals in this study indicate the content of classroom discussion and possible intentions, but do not establish that students changed their daily practices or that households became better prepared. Follow-up evidence would be needed to assess whether discussion led to sustained action.

Implementation Constraints

Two constraints were prominent. First, the school lacked a geography laboratory and equipment for activities such as drone-based observation. The source identifies computer-supported mapping as a desirable development, but no such use was documented. Second, the school library provided limited disaster-related materials and limited textbook variety, leading the teacher to develop worksheets and students to use smartphones for supplementary searches.

These conditions are consistent with categories of constraints identified in research on GIS implementation and teachers' technology use (Akram et al., 2022; Bernhäuserová et al., 2022; Spiteri & Chang Rundgren, 2020). The printed-image approach offered a manageable classroom alternative while retaining some access to digital information. Its limitations included the absence of interactive layers, coordinate-based analysis, and independently checked spatial outputs.

Improvement would require more than purchasing equipment. Research on teachers' digital roles, competence, and professional development supports considering instructional preparation and ongoing support alongside access (Falloon, 2020; Sims & Fletcher-Wood, 2021; Wohlfart & Wagner, 2023). Future lessons could document image provenance, define the intended interpretation skill, and provide clear assessment criteria before introducing more advanced mapping tools. Appropriate task design would help students use additional facilities meaningfully.

Limitations and Educational Implications

This study is limited by its descriptive design and incomplete numerical reporting. The total class size, implementation dates, duration, assessment criteria, minimum mastery threshold, and individual scores were not stated. The teacher observed and assessed the activities, with no independent observer or reliability information reported. There was no comparison group, and the available evidence cannot isolate a causal learning effect.

The distinction between educational interpretation and operational flood assessment is equally important. Students marked places discussed as potentially flood-prone, but the study supplied no validated flood inventory, terrain analysis, rainfall or discharge measurements, or accuracy assessment. It did not measure preparedness behavior, actual flood exposure, or flood losses. Conclusions should therefore concern learning activities and reported classroom performance rather than verified reductions in disaster risk.

For educational practice, the experience shows how locally relevant imagery and worksheets can organize geography learning under limited facilities. Such design is compatible with attention to prior knowledge, meaningful participation, and supportive learning conditions (Darling-Hammond et al., 2020). Future evaluation could record complete assessment data, distinguish cognitive understanding from spatial performance, and assess digital literacy and participation separately. Any subsequent community activity should be documented as a separate outcome rather than assumed from the classroom discussion.

CONCLUSION AND RECOMMENDATIONS

Remote sensing teaching materials were implemented in class XII IPS 1 at SMAN 1 Pangkep through group analysis of flood causes, manual marking of potentially flood-prone locations, and presentation of findings. Imagery obtained from Google Maps, smartphone-supported information searching, and printed worksheets connected a difficult geography topic with a familiar local environmental issue. The source reported final achievement scores of 77–92 and stated that all students exceeded the school's mastery benchmark. The teacher also described stronger participation and appropriate correspondence between selected image locations and recognizable ground features.

These findings support the feasibility of the described classroom approach. They do not establish a statistically tested learning gain, a validated flood map, or an actual reduction in flood risk. The main contribution is a contextual geography learning sequence combining digital

information access with printed spatial representations and collaborative explanation.

Teachers are encouraged to provide clear image interpretation prompts, identify the sources and dates of imagery, and distinguish the accuracy of a spatial annotation from general task completion. Schools can strengthen geography resources and teacher support while retaining accessible printed materials where appropriate. Future research should report participant numbers, complete score records, assessment procedures, and independent evaluation of spatial work. Longer-term follow-up could examine whether knowledge and proposals are followed by preparedness or environmental actions, while technical flood assessment would require additional data and validation.

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