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Doctoral Dissertation

故事性地形特徵圖於印尼崩塌災害風險溝通的設計、評估與未來發展

Visual Story-based Geomorphological Map (VSGM) as Innovative Landslide Risk Communication Instrument in Indonesia: Design, Evaluation, and Future Development

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I vividly recall the first time I met **Prof. Lin Tsung-Yi**, whose inspiring guidance solidified my decision to pursue a PhD in Geography at **NTNU, Taiwan**. Following this meeting, I began the necessary registration procedures, and I was overjoyed to receive official acceptance for the Fall 2020 semester. Yet, life had unexpected challenges in store: the COVID-19 pandemic emerged at the end of 2019, sweeping through the globe and halting international travel. Despite these setbacks, including the widespread closure of borders and uncertainties regarding visa processes, my enthusiasm to embark on this academic adventure never waned. After several months of anticipation and delay, I finally arrived in Taiwan in October 2020, where I underwent strict quarantine measures. While the isolation was challenging, it remains one of the most profound and memorable experiences of my life, shaping my resilience and adaptability as I embarked on my doctoral journey.

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Abstract in Chinese

氣候變遷導致的崩塌災害威脅日益加劇，亟需有效的風險溝通工具來吸引更廣泛的社群參與並支持災害風險管理。所幸隨著製圖技術的進步，比以往更容易製作大比例尺的地形特徵圖，而有助於增強人們對崩塌災害和風險的空間覺察，並促進符合當地的減災策略。然而地形特徵圖的複雜性，常限制非地學專家使用這類地圖的可能性，因此，本研究提出一組向非專家使用者傳達山崩風險的創新工具—「視覺化之以故事為本的地形特徵圖」(Visual Story-Based Geomorphological Map，VSGM，簡稱故事性地形特徵圖)，並以印尼松賓火山地景 (Sumbing volcanic landscape) 為案例，探討「故事性地形特徵圖」在增進空間覺察和自主減災行動中的潛力。

「故事性地形特徵圖」包含一張衍生的地形特徵圖、一冊漫畫和一份使用說明，旨在傳達地形特徵圖在降低災害風險所能扮演的重要角色——從提升使用者對在地之崩塌災害和風險的空間覺察，到增強使用者能力而提出對具體情境的減災策略。本研究探討四個核心問題：VSGM 是如何設計的？根據地圖可用性(usability)其製圖品質如何？VSGM 對使用者識覺的影響程度為何？以及 VSGM 未來發展的策略為何？本研究採質性研究方法進行分析，包括：採用共同產製地圖的取徑 (co-production approach)；以半結構式訪談八位受訪者，評估地圖的可用性和使用者識覺；採用 SWOT 分析，提出 VSGM 未來發展的建議。

在 VSGM 開發過程中採用共同產製的取徑有兩個關鍵意義：一是使地圖目標與使用者需求一致，以提高資訊溝通成效；二是整合專業人士和使用者的回饋意見，以產出經過可讀性測試的高品質地圖設計。可用性評估顯示，VSGM 的製圖品質良好，其友善的使用者引導設計可讓讀圖者輕鬆理解該地圖的用途。雖然多數受訪者認為 VSGM 需要花時間學習，但他們有高度意願使用和分享此地圖，則反映了 VSGM 的實用性和其所激發的正向感受。對於未來 VSGM 的使

用，建議包括探索具資訊價值的地理視覺化技術、增強視覺故事元素、支援數位地圖格式，以及擴大合作夥伴關係以確保資源支持。

本研究的主要貢獻為改善大比例尺地形特徵圖對非專家的實用性，透過漫畫和使用說明等這類基於故事敘述的媒介整合，而能做更有效的崩塌災害風險溝通。相對於崩塌分區圖等傳統地圖的簡化表現形式，「故事性地形特徵圖」可傳遞詳細的科學資料，使非專家能在減災行動中充分利用地形特徵圖。此外，本研究也強調設計風險溝通地圖的重要性，不僅限於單向的資訊傳遞，還能積極吸引和鼓勵使用者應對在地真實地點的挑戰，讓使用者對地圖高度認可其實用性、引發正向感受並確保未來持續使用。最後，本研究的創新方法展現的可行性，可提供各領域科學家們參考，將自己專業製圖的成果讓更廣泛的非專家使用者更易於理解而更具有影響力。

關鍵詞：地形特徵圖、故事敘述、風險溝通、崩塌風險降低。

Abstract in English

The increasing threat of landslide hazards due to climate change highlights the critical need for effective risk communication tools to engage wider communities and support disaster risk management. Meanwhile, advances in mapping technology have enabled the creation of large-scale geomorphological maps that enhance spatial awareness of landslide hazards and risks, facilitating site-specific mitigation strategies. However, these maps remain predominantly accessible to geoscience experts due to their complexity, limiting their usability among non-experts. To bridge this gap, this study introduces the Visual Story-Based Geomorphological Map (VSGM), an innovative tool designed to communicate landslide risks to non-expert users. Using the Sumbing volcanic landscape in Indonesia as a case study, this research explores the potential of the VSGM to enhance spatial awareness and encourage proactive disaster risk reduction (DRR) actions.

The VSGM consists of a derivative geomorphological map, a comic, and an instruction sheet, all designed to communicate the essential roles of geomorphological maps in disaster risk reduction—from fostering the local spatial awareness of landslide hazards and risks to empowering users in designing context-specific mitigation strategies. This study investigates four central questions: How was the VSGM designed? How does its cartographic quality base on map usability? To what extent does the VSGM shape user perceptions? And what strategies should guide its future development? These questions are addressed through qualitative methods, including a co-production approach to map creation, semi-structured interviews with eight respondents to assess usability and user perceptions, and a SWOT analysis to provide recommendations for advancing the VSGM.

The co-production approach in VSGM development serves two critical roles: aligning map objectives with user needs for heightened communication efficacy and integrating feedback from professionals and users for a high-quality, readability-tested design. Usability evaluations show that the VSGM offers satisfactory cartographic quality, with user-friendly navigation enabling users to readily discern its purposes. Although most respondents found the VSGM challenging to master, their high willingness to use and share it underscores its perceived usefulness and the positive emotions it inspires. Recommended strategies for future VSGM utilization include exploring informative geovisualization techniques, enhancing visual storytelling elements, supporting digital map formats, and expanding partnerships to secure necessary resources.

This research contributes to improving the utilization of large-scale geomorphological maps for more effective landslide risk communication among non-experts. By integrating storytelling-based media, such as comics and instructional sheets, it moves beyond the traditional oversimplification of maps into landslide zoning maps, which often omit critical information. Instead, this approach facilitates the communication of detailed scientific data, enabling non-experts to fully harness the benefits of geomorphological maps for disaster risk reduction (DRR). In addition, this study also underscores the importance of designing risk communication maps that move beyond one-way information delivery to actively engaging and motivating users to address site-specific challenges, thereby offering high perceived usefulness, eliciting positive emotions, and ensuring sustained future use. Eventually, this innovative approach presents significant potential for adoption by scientists seeking to make their specialized maps more accessible and impactful for broader, non-expert audiences.

Keywords: Geomorphological map, storytelling, risk communication, landslide risk reduction.

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Progress and challenges in designing landslide maps for disaster risk communication: a systematic review

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ABSTRACT
There has been a limited amount of research focused on the design of landslide maps, which are considered as one of the potential means to communicate disaster risks to the public. Hence, this article aims to conduct a systematic review of the process involved in creating landslide maps specifically for the purpose of disaster risk communication with non-expert users. While this topic is still under-studied, it has gained increasing coverage in the peer-reviewed literature over the past five years. The review examines the variations in the process of creating landslide maps, considering aspects such as planning, mapping techniques, presentation, and dissemination. However, there are several areas that require improvement, including diversifying the types of maps, considering the role and involvement of users, developing more user-friendly designs, and reducing reliance on experts during the dissemination process. The findings of this review provide valuable insights into the current limitations in establishing these maps and offer guidance for future research in this field.

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Understanding the nature of landslides through detailed geomorphological mapping on the Sumbing Volcanic Landscape, Java Island, Indonesia

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ABSTRACT
A 1:2,500-scale geomorphological map was created to illustrate the landslide characteristics on the southern flank of the Sumbing Volcanic Landscape (SVL), Java Island, Indonesia. High-resolution LiDAR Digital Terrain Model (DTM), Global Navigation Satellite System (GNSS) data, Unmanned Aerial Vehicle (UAV)-based aerial photographs, and field surveys were integrated to enable detailed landform interpretation of post-volcanic mass wasting processes. Landslides were classified by type, activity level, and origin. Additionally, morphometric analysis, including slope and area measurements, was conducted. Through this detailed geomorphological mapping process, it reveals that most recent landslides have developed within relict landslides, which were previously overlooked. It also detects smaller, more hazardous landslides caused by human activities, in addition to those triggered by natural forces. This study represents the first large-scale geomorphological mapping effort integrating high-resolution datasets in Indonesia's dormant volcanic landscapes. It will enhance understanding of landslide characteristics and will support disaster management strategies.

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Chapter 1 - Introduction

1.1. Background of the research

Landslides have caused widespread devastation across many countries, particularly in developing nations like Indonesia, where geographical vulnerability and socio-economic challenges exacerbate the risks. Over the past decade, these events have resulted in the loss of over a thousand lives and the displacement of hundreds of thousands of individuals, severely disrupting communities and local economies (BNPB, 2021). In addition to the immediate human toll, landslides often destroy infrastructure, agricultural land, and vital resources, leading to long-term socio-economic challenges for affected areas. Unfortunately. the risk posed by landslides is expected to escalate due to the increasing population in landslide-prone areas and the rising frequency of extreme rainfall events driven by climate change (Chiang & Chang, 2011; ISDR-ICL, 2015). These factors suggest that the severity and impact of landslides will likely grow in the coming years.

In efforts to reduce disaster risk, the International Landslide Consortium stresses the need for not only focusing on implementing early warning systems and improving infrastructure, but also developing tools like maps that can effectively communicate landslide risks to the wider community (Alcántara-Ayala & Sassa, 2021). Maps are invaluable for conveying the spatial and temporal characteristics of hazards and vulnerabilities, helping key stakeholders—such as government officials, planners, and communities—understand the geographic context of risks (Albano & Sole, 2018). This understanding is crucial for making informed decisions in spatial planning and disaster mitigation. Maps also foster collaboration and open dialogue among experts, authorities, and the public, promoting a more coordinated approach to disaster risk management. By translating complex scientific data into accessible visual formats, maps bridge the gap between technical knowledge and practical application, empowering stakeholders to take informed action. This trust-building tool not only enhances preparedness but also encourages communities to adopt safety measures, making maps essential for both immediate disaster risk reduction and long-term resilience efforts (Dransch et al., 2010; Tsai et al., 2021).

In Indonesia, despite some efforts have been conducted to develop map-based landslide risk communication tools, many existing maps lack the clarity and detail necessary to effectively understand the nature of hazard and risk. For example, the landslide hazard zoning map by Karnawati et al., (2018) is overly simplistic, omitting critical visual elements such as the shape and activity of landslides as well as causative factors like topography, river channel, and human-induced slope modifications. These details are crucial for understanding about hazard characteristics, including where landslides might occur, why they happen, their frequency, and their magnitude. Similarly, the risk zoning maps developed by Fathani et al., (2016) and Setiawan et al., (2021) which emphasize risk levels, are prone to misinterpretation, as residents in medium- or low-risk zones may underestimate the danger and fail to adopt appropriate mitigation measures (Purworini et al., 2021) (Figure 1.1). This underscores the importance of developing more detailed, context-rich maps to enhance understanding of landslide hazards and to motivate risk reduction efforts across all zones, aligning with the core objectives of disaster risk communication.

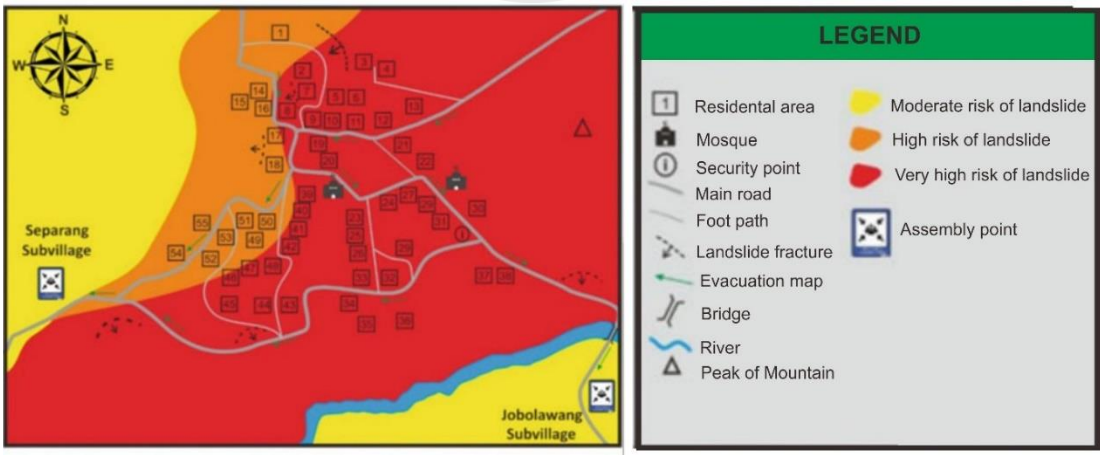


Figure 1.1 The example of map visualization for landslide risk communication tool in Indonesia published by Setiawan et al., (2021)

Geomorphological maps, which focus on visualizing the earth's surface shape and the processes that form it, hold great potential as tools for communicating landslide hazard and risk (Davies et al., 2021). It is because at a detailed scale, these maps can effectively display information about the location, shape, and characteristics of natural processes that modify the earth's surface, including small-scale events like landslides (Hearn, 2019; Viganò et al., 2021). Additionally, detailed geomorphological mapping can capture the human activities which also alter the landscape, such as agricultural terraces, slope cutting, settlement development, and road construction (Raso et al., 2021). By combining detailed information on both landslide characteristics and human activities features, these maps offer a more realistic and comprehensive visual representation of landslide hazards and risks, enhancing public understanding and supporting better-informed risk management decisions.

However, it cannot be denied that delivering complex information, such as detailed geomorphological maps, to non-expert users presents significant challenges (Griffiths & Abraham, 2008a). Geomorphological maps often contain technical and specialized data, including intricate representations of topography, geological features, and natural processes, which may be difficult for individuals without a background in geoscience to interpret effectively. The complexity of such maps, combined with the use of scientific terminology and symbols, can lead to confusion or misinterpretation, particularly among community members or decision-makers who are not trained in cartography in general (Meyer et al., 2012) or geomorphology in specific. However, the absence of critical information can impede users from understanding the full benefits of the map. Thus, developing strategies to clearly convey content-rich geomorphological map without causing confusion among map users is crucial. When scientists succeed in designing maps that are vivid and easy to understand, they become valuable tools across various professions, leading to broader dissemination and application (Driedger et al., 2024).

On one side, the storytelling approach in cartographic design has increasingly gained attention due to its potential to improve the accessibility and comprehension of maps for non-expert users. By incorporating narrative structures, storytelling transforms maps into dynamic communication tools, presenting information in a way that aligns with how people naturally process stories (Dahlstrom, 2014). This makes maps more intuitive, engaging, and relatable, guiding users through a sequence of events or processes in a compelling and persuasive manner (Roth, 2021a). However, despite its potential, there is a notable lack of empirical research on the effectiveness of map-based visual storytelling. Song et al., (2022) call for more studies to explore how storytelling techniques can be applied to various contexts of cartographic design and to assess their benefits in enhancing map usability and impact on the targeted users.

This study intended to introduce an innovative approach to landslide risk communication by developing the Visual Story-based Geomorphological Map (VSGM), which integrates visual storytelling techniques with traditional geomorphological mapping. The goal of incorporating visual storytelling is to make complex geospatial information more accessible and engaging, particularly for non-expert users, by presenting data in a narrative format that reflects everyday communication patterns. This approach addresses the challenge of conveying intricate environmental processes, such as landslides, in an intuitive and relatable way for individuals from non-geoscience or non-geomorphology background. By integrating scientific accuracy with an engaging visual narrative, the VSGM has the potential to significantly enhance how landslide hazards, causative factors, and potential impacts are communicated to the non-experts, thereby motivating them to use it for more practical risk reduction measures.

The scope of this study extends beyond the design phase, encompassing a thorough evaluation of the VSGM's usability and its impact on users' perceptions of the role of geomorphological maps in landslide risk reduction. The results of this evaluation will provide valuable insights into how well the map meets its intended objectives, helping to identify areas for improvement and shaping strategies for its future development. Designed specifically for disaster communicators from government and non-governmental organizations (NGOs), who may lack formal geoscience training, the VSGM delivers complex geospatial data into an accessible format. The prototype will be developed and field-tested in Magelang, Central Java, a high-risk area for landslides, to assess its real-world applicability and effectiveness in supporting disaster risk reduction efforts. The insights gained from this case study will inform the broader application and refinement of the VSGM as a tool for landslide risk communication in Indonesia and other vulnerable regions.

1.2. Research problem or question

The storytelling approach has been widely recognized for its potential to communicate scientific information effectively to audiences beyond the academic community. Numerous researchers have explored how storytelling can enhance science communication by making complex concepts more accessible. Similarly, cartographers have highlighted the advantages of incorporating storytelling into map design to create user-friendly, visually engaging mediums for conveying scientific data (Caquard & Cartwright, 2014; Lindahl, 2012). Roth, (2021) comprehensively reviewed the role of storytelling in cartographic design, offering detailed guidance on structuring narratives and visually embedding them into maps. Despite these theoretical advancements, there remains a significant gap in empirical research demonstrating how storytelling can be applied across different map contexts.

Map-based visual storytelling for disaster risk communication is critically underrepresented in scholarly literature. While some research has examined the application of storytelling in maps for various purposes—such as conveying earthquake impact scenarios to local governments in China (Rodgers et al., 2020), raising awareness of sea level rise in Flensburg, Germany (Vollstedt et al., 2021), and enhancing the usability of flood hazard maps for emergency response in Dordrecht, the Netherlands (de Bruijn et al., 2016)—the subject of landslide risk communication remains largely unexplored. Moreover, although previous studies have focused on designing maps that meet user needs through storytelling, there has been little evaluation of their effectiveness as disaster communication tools. Key questions about the quality of cartographic design, such as how easily users can navigate the maps, as well as questions about user perceptions, including how they assess the map's usefulness and whether it promotes future use, largely remain unanswered.

Therefore, developing innovative map designs that integrate storytelling techniques into traditional geomorphological maps for effective landslide risk communication is a relatively unexplored area. To carry out this topic of research, several key questions need to be addressed. First, how can map designs be made user-friendly while addressing the specific needs of their target audiences, particularly non-experts such as disaster communicators? Secondly, how good is the cartographic design in ensuring that complex scientific information is communicated clearly and efficiently? Additionally, how does the map design influence users' perceptions of its usefulness in disaster risk reduction agenda? Does it foster positive views of its benefits and motivate users to rely on it in the future? Exploring these questions is crucial to make sure that the map design has a good quality and effective as a tool for conveying landslide risks.

1.3. Research objectives

This study aims to propose a Visual Story-based Geomorphological Map (VSGM) as an innovative tool for landslide risk communication and to evaluate its effectiveness in order to develop recommendations for future enhancements. The VSGM was designed to convey the essential roles of geomorphological maps in landslide risk reduction and to foster a positive perception of their value in supporting disaster management efforts. Specifically, the VSGM is tailored for disaster communicators from local governments or NGOs who lack a formal geoscience background. To achieve the main objective, the study addresses the following sub-objectives:

1) Create a user-friendly design of Visual Story-based Geomorphological Map (VSGM) using co-production technique.
2) Evaluate the cartographic quality of the VSGM design by analyzing its usability through semi-structured interviews.
3) Evaluate users' perception after using VSGM design by analyzing their cognitive, affective and conative using semi-structured interview.
4) Conduct a SWOT analysis to develop recommendations for the future enhancement of the VSGM as an effective tool for landslide risk communication, with a focus on Indonesia and broader applicability in other vulnerable regions.

1.4. Significance of the research

The significance of this research lies in its potential to address several key gaps and challenges in landslide risk communication, particularly in the context of non-expert users such as local government officials and NGOs. This research also contributes to the advancement on the disaster risk communication, cartography, geomorphology, and the broader field of disaster management both theoretically and practically. The significance of this research is outlined in more detail below:

1. Innovative approach to risk communication. Visual Story-based Geomorphological Map (VSGM) as a novel tool that integrates storytelling techniques with basic geomorphological mapping. This innovative approach can enhance the way landslide risks are communicated, making complex geoscientific data more accessible and engaging to non-expert audiences.
2. Filling a Research Gap: Map-based visual storytelling for disaster risk communication, particularly for landslides, is an under-explored field. This study contributes to this emerging area by developing and evaluating a map specifically designed for landslide risk communication, offering a new perspective on how to make geomorphological maps more user-friendly and effective.
3. Evaluation of Map Effectiveness: this research not only proposes a new design but also rigorously evaluates its effectiveness through user testing. This empirical evaluation will provide valuable evidence on how visual storytelling can enhance the usability, perception, and impact of maps used in disaster risk communication.
4. Practical Application: The VSGM is tailored for disaster communicators from local governments and NGOs who do not have a geoscience background. This makes the research highly practical, as it provides a tool that directly supports those involved in disaster risk reduction and management, allowing them to better understand and communicate landslide risks to the public and stakeholders.
5. Enhancing Disaster Preparedness: By improving the usability and effectiveness of landslide risk maps, this research has the potential to enhance disaster preparedness and mitigation efforts. It supports informed decision-

making and risk communication, which is crucial for reducing the impact of landslides in high-risk areas like Indonesia and beyond.

6. Broader Implications for Vulnerable Regions: While focused on Indonesia, the insights and recommendations from this research can be adapted and applied to other regions facing similar landslide risks. This research potentially gives global relevance and influences disaster communication strategies in various vulnerable regions.

Chapter 2 - Literature Review

2.1. Geomorphological map and its role in landslide risk reduction

2.1.1. Geomorphological map definition

A geomorphological map is a map that illustrates the landforms and surface features of a region, focusing on the processes that shape them over the time (Huggett, 2017). Unlike a geological map, which primarily focuses on the distribution, structure, and age of rocks and the Earth's subsurface layers, a geomorphological map highlights earth surface processes and landform evolution. It is also different from a topographical map which highlights elevation and terrain shape through contour lines (Figure 2.1(a)), a geomorphological map focuses on interpreting the underlying causes of terrain variations, such as formation by fluvial processes, landslides, or human activities (Figure 2.1(b)). By identifying landforms, geomorphological maps enable the understanding of past and potential future natural processes, even those not currently visible or directly observable on the ground (Figure 2.1(c)).

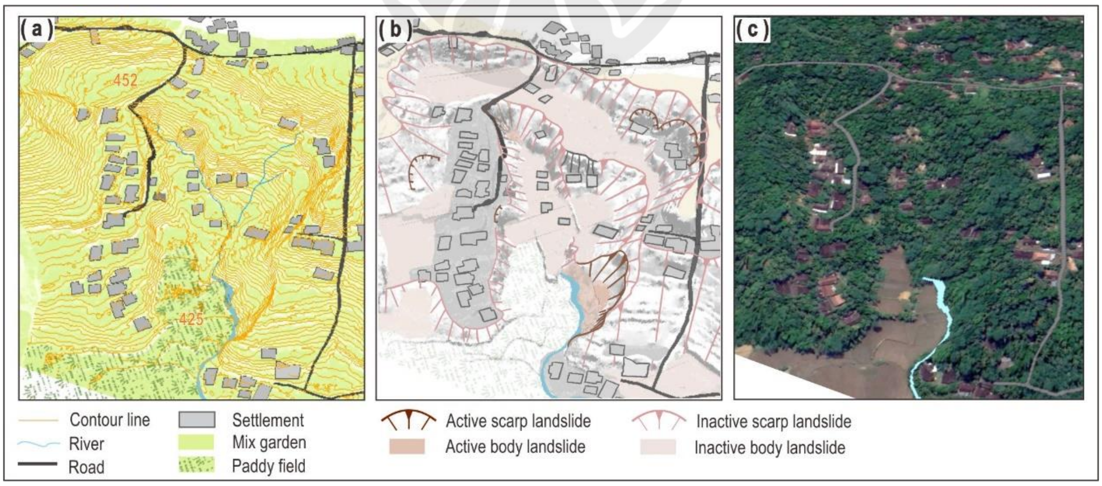


Figure 2.1 The distinction in how topographic and geomorphological maps present environmental information for areas that may appear safe from landslide threats. (a) Topographical map. (b) Geomorphological Map. (c) Google earth satellite that represents the real-word conditions.

2.1.2. Geomorphological map scale

Geomorphological maps can be created at various scales, each offering a unique level of detail about landform features. These differences in detail, known as the hierarchical sequence of landforms (Figure 2.2), highlight the diverse characteristics of landscapes across scales. As explained by (Smith et al., 2011), small-scale geomorphological maps (typically smaller scale than 1:250,000), which cover global or large regional areas, depict major landforms shaped by long-term processes occurring over millions of years, such as dormant volcanic foothills, volcanic cones, or volcanic lakes. In contrast, medium-scale maps (typically between 1:25,000 to 1:250,000) focus on smaller landforms that reflect significant changes over hundreds to thousands of years, driven by a complex interplay between endogenic and exogenic processes influenced by climate. For instance, in dormant volcanic foothills, medium-scale maps might reveal the effects of incision processes caused by both gravitational and surface water force, forming distinct hillslope patterns, alongside deposition processes that create valleys.

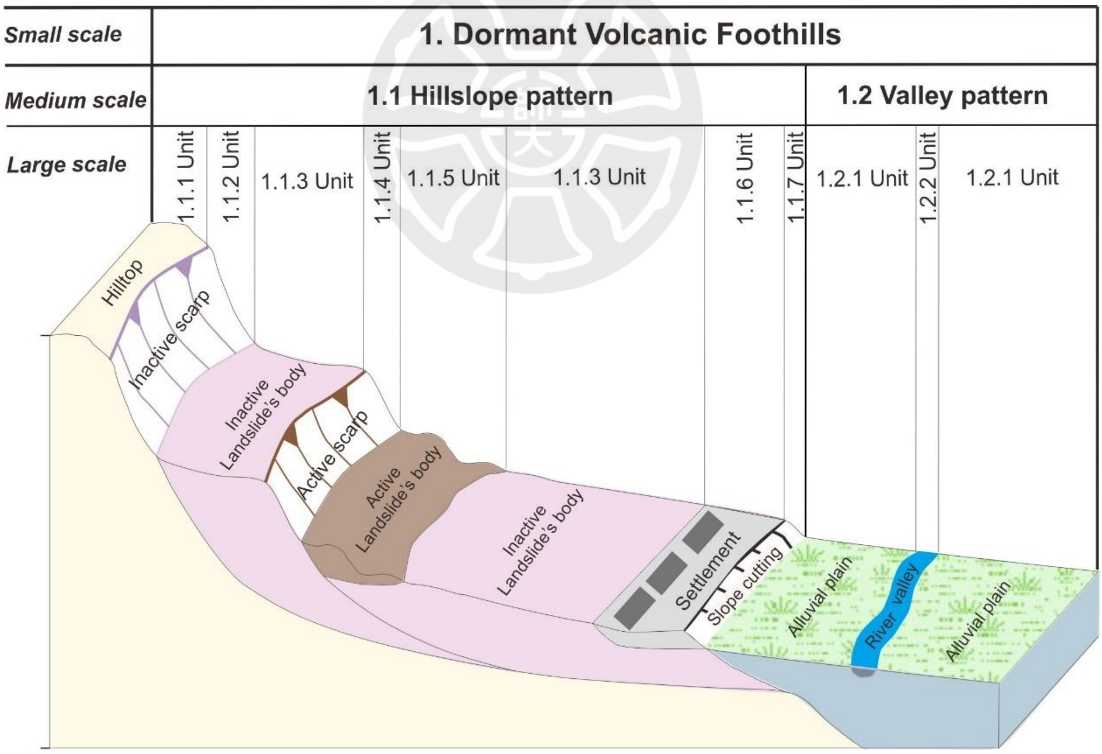


Figure 2.2 The illustration of landform hierarchy in each map scales.

At a large scale (typically larger scale than 1:25,000), which focuses on smaller areas, geomorphological maps depict finer details of landforms shaped by short-term processes, often occurring within less than a century. For instance, within the dormant volcanic hillslopes, smaller landform units influenced by current gravitational forces can be identified, such as the scarps and bodies of inactive and active landslides. At this scale, geomorphological maps also highlight anthropogenic landforms, acknowledging the significant role of human activities in reshaping the Earth's surface. These human-made features may include agricultural terraces, cut-and-fill slopes, road networks, settlement platforms, and other modifications introduced by human intervention. These varying scales provide invaluable insights into the dynamic evolution of landscapes.

2.1.3. Geomorphological map cartographic design.

The cartographic design of geomorphological maps, like the creation of any map, must adhere to established cartographic principles to ensure clarity, accuracy, and effectiveness. Designing such maps requires careful consideration of at least four key aspects that define the map's context and guide its design. These aspects are the **purpose** of the map, the **audience** it is intended for, the **environment** in which it will be used, and the method of **map presentation** (Tyner, 2014). Thoughtful attention to these elements ensures that geomorphological maps are not only scientifically robust but also accessible and meaningful to their intended users.

1) **Map Purpose.** Map purpose refers to the specific objective or goal for which a map is created. It defines the type of information a map should convey. Defining the purpose of a map is a crucial step before its creation. According to Dramis, F., and Bisci, C., (1998) in Smith et al., (2011) geomorphological maps can generally be categorized into two types based on their intended purpose. The first type is the **Basic Geomorphological Map**, which focuses on presenting purely geomorphological information. These maps emphasize the distribution, characteristics, and dynamics of landforms and are primarily designed for use by geomorphologists or the geoscience community. The second type is the **Derivative Geomorphological Map**, which is created through the selection, generalization, and reinterpretation of data from basic maps to serve specific

objectives. As a result, derivative maps are simplified and more user-friendly, making them accessible to non-geomorphologists. This type of geomorphology map has very diverse objectives and messages, such as for disaster risk reduction needs, spatial planning, or ecotourism.

2) **Map Audience.** Map audience or user refers to the individuals, groups, or organizations for whom the map is created and who will use the map to achieve specific goals or gain insights. Understanding the audience is essential for tailoring the map's design, content, and complexity to align with their needs, skill levels, and usage contexts. In the case of geomorphological maps, the audience can generally be categorized into two major groups. The first group comprises **geomorphological experts** and the geoscience community, who primarily use basic geomorphological maps for research and analysis. The second group includes **non-geomorphologists**, such as **non-experts** or novice users, who tend to rely on derivative geomorphological maps designed for easier interpretation and practical applications. Shen et al., (2023) highlight examples of potential map users, ranging from experts in the field to novices, demonstrating the diverse scope of geomorphological map users (Figure 2.3).

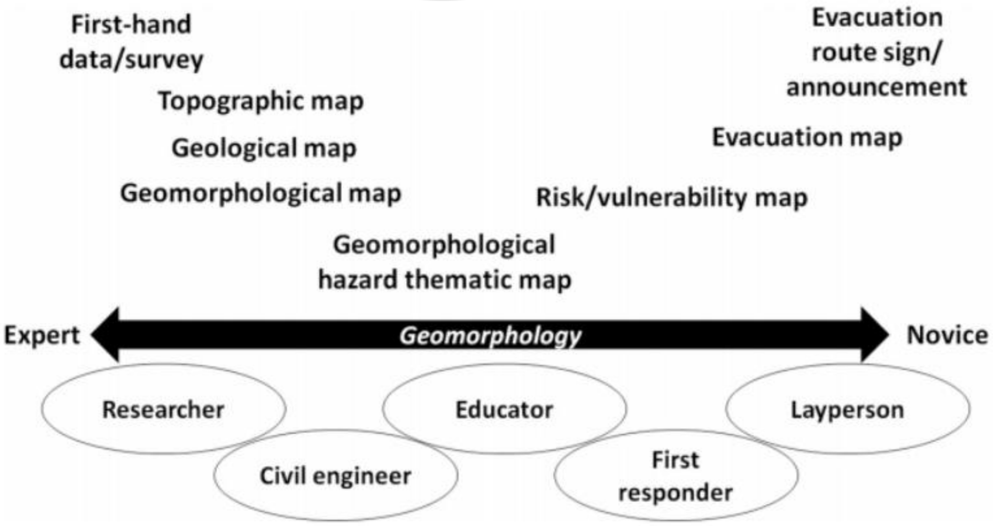


Figure 2.3 Spectrum of geomorphological map users and the types of derivative maps they require (source: Shen et al., (2023))

3) **Map Environment.** The map environment refers to the context and conditions in which users interact with a map. Understanding these conditions is crucial for determining the most suitable materials, media, and design features for effective map representation. For instance, whether the map will be used indoors or outdoors, as a handheld reference or a wall display, and under natural sunlight or artificial lighting can significantly influence design decisions. Thoughtfully planning the specific conditions of map use allows map makers to tailor essential elements, such as font size, colour contrast, symbol dimensions, and material durability, to enhance usability and ensure the map serves its intended purpose effectively.

4) **Map presentation.** Map presentation refers to the process of designing and displaying a map in a way that optimally conveys its intended information to the target audience. This involves deliberate planning and careful consideration of various elements to ensure clarity, usability, and aesthetic appeal (Tyner, 2014). One of the primary considerations is the **interface**, which determines whether the map will be in a traditional paper format or a digital, web-based format. Each interface has unique advantages and challenges; for example, paper maps offer portability and simplicity, while web-based maps allow for interactivity and dynamic data updates.

   Additionally, **map scale** plays a crucial role in presentation, as it dictates the level of detail that can be included and how effectively the map can communicate spatial relationships. The choice of data sources ensures the accuracy and reliability of the information, while the **type of information/data** guides the map's overall design. **Symbolization**, including the size, colour, and style of symbols, is another vital aspect, as it aids in distinguishing features and emphasizing key elements.

   Finally, the **map layout** integrates all these components into a cohesive and visually appealing design. Elements such as the title, legend, scale bar, compass rose, and margins must be organized logically to facilitate easy interpretation. By carefully addressing these factors, the map maker ensures that the map is both functional and tailored to the needs and expectations of its users.

2.1.4. The role of geomorphological map in landslide risk reduction

The geomorphological map's ability in presenting landforms and the dynamic processes that shape them makes it highly effective for understanding the geographical context of natural hazards, such as landslides (Chelli et al., 2021; S. M. Shen et al., 2023). Landslides, as previously mentioned, are natural processes that actively reshape the landscape; however, they become hazardous when they pose a threat to human inhabitants. Through detailed geomorphological mapping, the locations of historical landslide events can be identified, as evidence of past landslides often manifests in distinct landforms like scarps, hummocky slopes, and soil fractures (Dotta et al., 2023; Frodella et al., 2014). When spatial data on landslide distribution are analysed in conjunction with surrounding physical environmental aspects such as slope, river network, geological condition or human intervention on land, it becomes possible to identify not only the causative factors but also areas susceptible to landslides (Chen & Huang, 2013; Gaidzik et al., 2017; Martinello et al., 2024).

Geomorphological mapping also deals with monitoring landslide dynamics, which is essential for assessing hazard levels (Li et al., 2014). Temporal observations of landslide events provide valuable insights into the frequency and recurrence of landslide processes in a given area, as well as whether land movement is still ongoing in previously affected regions. This temporal data allows landslides to be categorized as either active or inactive (WP/WLI (International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory), 1993). An active landslide is characterized by continued movement of soil or rock masses over time, whereas an inactive landslide shows no detectable movement for an extended period. This classification is crucial for hazard analysis, as areas surrounding active landslides present a higher potential for future reactivation, making them more dangerous compared to inactive zones (Lo et al., 2017).

Due to their robust capacity to represent the location, dimensions, contributing factors, and activity stages of landslides, geomorphological maps are not only critical for hazard assessment but also serve as a valuable tool for forecasting potential landslide scenarios and their associated impacts. Mapping landslide hazards alongside socio-cultural environments allows for the estimation of potential landslide impacts (Cardinali et al., 2002). This information is essential for identifying high-risk areas and designing strategies to reduce disaster risk in the future.

In summary, Davies et al., (2021) outline four critical roles of geomorphological maps in reducing landslide risk (Figure 2.4). First, these maps can be used for identifying landslide location because they provide a historical record of landslide occurrences by recognizing landform evidence such as scarps, debris flows, and displaced material that reveal past events. Second, geomorphological maps offer insight into the nature of landslides, detailing the processes and environmental factors—such as slope gradient, soil composition, and hydrological process or anthropogenic disturbance—that contribute to landslide formation. Third, by analysing these contributing factors alongside historical data, geomorphological maps facilitate the prediction of potential hazard scenarios, allowing for an estimation of their likely impacts on landscapes and communities. Finally, this capability makes these maps valuable for designing targeted mitigation strategies, enabling planners and policymakers to prioritize risk reduction efforts, protect vulnerable areas, and enhance disaster resilience within at-risk communities.

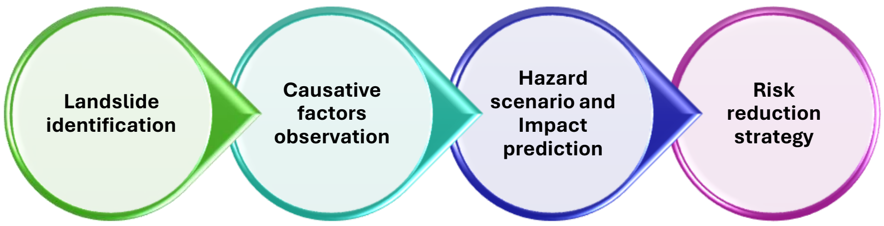


Figure 2.4 Four essential roles of geomorphological map in landslide risk reduction agenda.

2.2. Landslide risk communication

2.2.1. Disaster risk

With the increasing frequency of disaster events, the study of disaster risk has gained significant attention and developed rapidly. Understanding the conceptual foundations of disaster risk, including its root causes and drivers, is critical for identifying preventive measures to mitigate future risks. Disaster risk is commonly defined as a function of hazard, exposure, and vulnerability, often quantified as the probability of significant losses—whether in human lives or tangible and intangible assets—suffered by a community within a specific timeframe (UNISDR, 2009). Building on this concept, the components of risk are identified as hazard, exposure, and vulnerability (Oliver-Smith et al., 2016) (Figure 2.5).

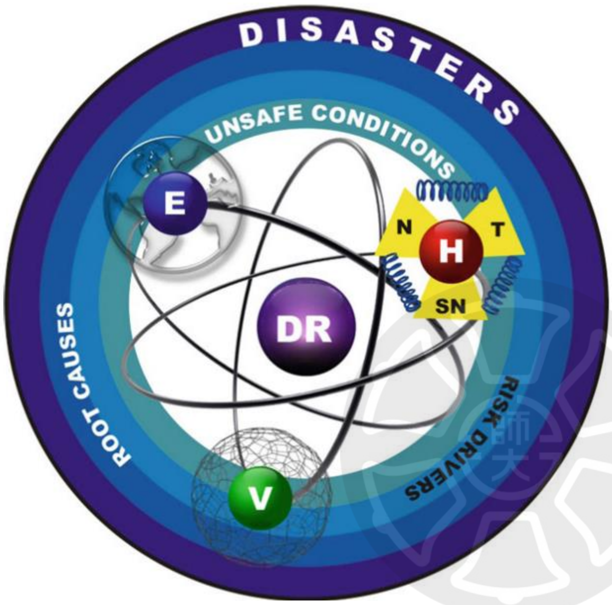


Figure 2.5 A diagram illustrating the construction of disaster risk (DR) as the outcome of the interaction between Hazard (H)—whether stemming from natural (N), technological (T), or socio-natural (SN) sources—and exposure (E) dan Vulnerability (V). (Source: Oliver-Smith et al., (2016))

Exposure refers to the presence of people, infrastructure, housing, production capacities, and other tangible human assets in areas prone to hazards. Vulnerability, on the other hand, encompasses the physical, social, economic, and environmental characteristics or processes that increase the susceptibility of individuals, communities, assets, or systems to the adverse effects of hazards. This framework underscores that disaster events are deeply intertwined with social constructs; they occur only when a hazard has the potential to result in human, material, economic, or environmental losses.

2.2.2. Risk communication

The discourse on risk communication has a long history, growing alongside advancements in civilization and scientific understanding. Defined by the

National Research Council, (1989) as an "interactive process of exchanging information and opinions about the nature of risk," risk communication involves sharing insights and concerns about risk among individuals, groups, and institutions. This exchange is not only limited to conveying risk-related information but also includes broader signals of safety, confidence, and strategies for community cohesion or advocacy (Plough & Krimsky, 1987). Therefore, this exchange of information across multiple levels—individuals, organizations, and institutions—has influences on how people understand, interpret, and respond to risk. As Lin et al., (2020) describe, risk communication process does more than alter personal risk perceptions; it also influences behavioural outcomes, including the decisions individuals and groups make in response to potential threats (Figure 2.6). From this perspective, "educating" about the risk and "persuading" the public to take proper actions then become central components of any effective risk communication strategy (Bourrier & Biede, 2018).

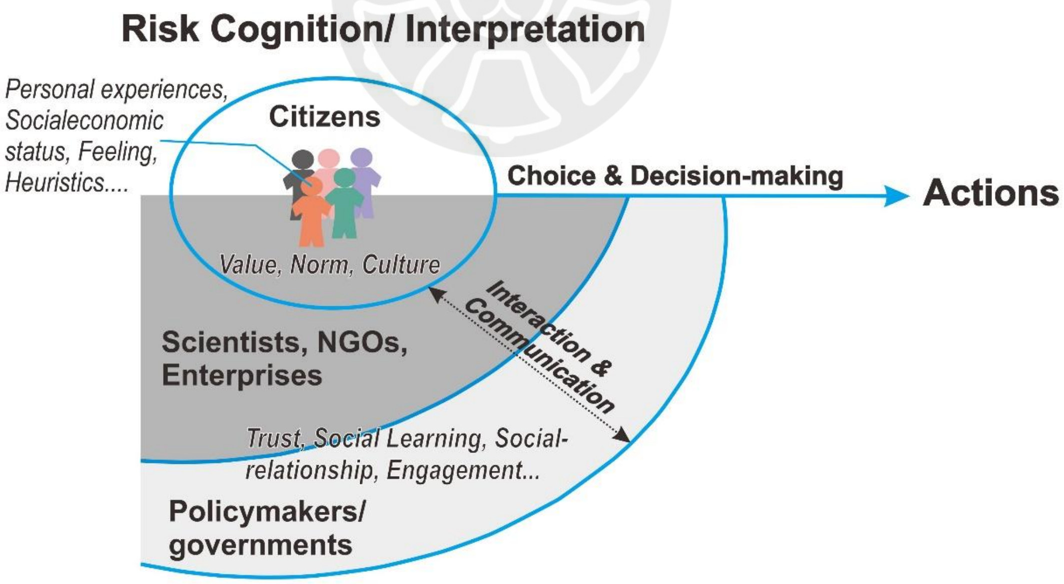


Figure 2.6 The framework of risk communication visualized by Lin et al., (2020)

Actors, purposes, tools, and **messages** are the pillars that must be considered in effectively implementing risk communication (Höppner et al., 2010). **Actors** encompass all individuals or groups involved in the process, including both those who convey information and those who receive it. Key actors in risk communication can include a wide range of stakeholders, such as local and central governments, policymakers, politicians, scientists or experts, industry representatives, non-governmental organizations, the affected community, and the key persons on natural hazards from lay villagers. As outlined (Lin et al., 2020) , while a variety of information types can be conveyed, the purposes of the risk communication should be to enhance people's understanding of risks. This improved knowledge serves as a foundation for informed decision-making, enabling individuals and communities to make optimal choices and take effective actions to reduce disaster risks.

The selection of tools or media for transmitting information to recipients is a critical consideration in effective risk communication. Communication tools may encompass verbal, written, auditory, or graphic methods, each requiring careful evaluation to ensure appropriateness for the target audience. Regardless of the medium employed, the development of user-friendly tools is essential to the success of the communication process. Designing tools that are both visually appealing and easy to interpret enhances the likelihood that recipients will fully and accurately comprehend the intended message. In addition, the formulation of the message itself must be precise and unambiguous. Clear messaging is a fundamental determinant of the effectiveness of the communication process, as it directly influences the extent to which the information is understood and acted upon by the audience.

Adopting concepts from information theory, the process of communicating risk involves identifying five fundamental elements: the information source, the transmitter, the channel, the receiver, and the destination (Shannon, 1948). These elements are illustrated on the Figure 2.7 defined as follows:

1. **Information source**: The origin that generates the message to be delivered to the receiving terminal.
2. **Transmitter**: The mechanism or system that processes the message into a format suitable for transmission over a communication channel.
3. **Channel**: The medium or tool through which the signal is transmitted from the transmitter to the receiver.

4. **Receiver**: The component that performs the inverse operation of the transmitter, reconstructing the original message from the transmitted signal.
5. **Destination**: The individual or entity for whom the message is intended.

Each of these elements must be carefully designed and implemented to ensure the success of the risk communication process, as their effectiveness directly impacts the clarity, accuracy, and accessibility of the conveyed message.

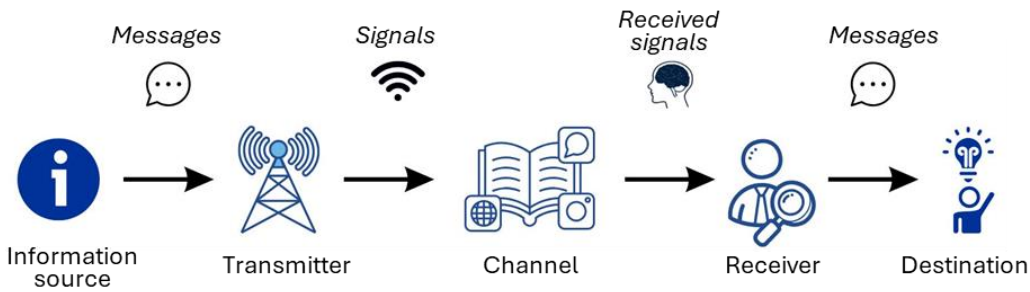


Figure 2.7 The illustration of the elements and flow on the general communication adopted from Shannon, (1948)

2.2.3. Landslide risk communication

Based on the theory and concept of risk communication, landslide risk communication itself can be understood as the process of transferring knowledge or information about landslide risks among individuals, communities, and relevant stakeholders with the goal of influencing perceptions and motivating actions to reduce or manage disaster risk. Effective landslide risk communication requires a comprehensive presentation of what constitutes risk, including the causes, potential impacts, and pathways to mitigation. According to Alcántara-Ayala, (2018), landslide risk communication should emphasize not only understanding the hazard itself but also exploring the multi-dimensional nature of vulnerability, the social constructs surrounding landslide risk, and the need for an integrated approach to risk management. Ultimately, it is about fostering a shift from a reactive, disaster-response model to one focused on proactive risk management, empowering communities to anticipate and mitigate landslide risks more effectively.

2.2.4. Maps for landslide risk communication

Maps are one of the channels or tools for communicating risk. Maps for landslide risk communication should be developed to meet the primary objectives of risk communication: to educate the public on hazards and risks and to promote behaviours that enhance risk mitigation. To achieve this, (Dransch et al., 2010) suggest three critical components for effective map-mediated risk communication: enhancing personal risk perception, supporting personal risk framing, and establishing credibility information. Therefore, designing such maps is a complex endeavour, requiring expertise in selecting appropriate methods for presenting spatial-temporal hazard and risk information in an accessible manner and employing geovisualization techniques that closely replicate real-world contexts to build user trust.

To date, designing maps for communicating landslide risk to non-expert audiences presents significant challenges for scientists. One of the primary challenges is the inherent uncertainty of landslide events, which are both undesired and difficult to predict. This uncertainty complicates communication efforts as people struggle to understand the probabilistic nature of such risks and may not fully grasp the potential for future occurrences. Maps that unable to inform “where” “why” “how often” and “how big” a landslide will occur can lead to confusion or apathy, especially when there is a lack of supporting data and information provided.

When scientists have sufficient data, a significant challenge remains in translating and visualizing this scientific information in a way that is easily comprehensible to non-experts (Driedger et al., 2024). Recent advancements in remote sensing technology have contributed substantially to the progress of landslide studies. For instance, LiDAR technology now enables the creation of high-resolution Digital Terrain Models, allowing for detailed visualization of the earth's surface and the identification of landslide features (Jaboyedoff et al., 2012; Verbovšek et al., 2019). Similarly, the increasing affordability of UAVs (Unmanned Aerial Vehicles) has made it possible to capture images of landslide events on demand, facilitating the monitoring of landslide activity (Kowalski et al., 2018; Niethammer et al., 2012). Despite these technological advances, limited attention has been given to making such data accessible and useful to non-expert audiences in support of landslide risk reduction efforts. Thus, researchers must consider which geovisualization techniques are both informative and easily understandable for the intended map users (Fuchs et al., 2009).

Another challenge in landslide risk communication is how to design maps that can motivate practical behavioural change among the users. Creating effective maps for risk communication must do more than just inform people about the existence of hazards and risk; it should inspire concrete actions. This involves not only making people aware of the severity and immediacy of the risk but also fostering a sense of personal responsibility and empowerment to take preventive measures (Paton, 2008). (Alcántara-Ayala, 2018) also highlights that risk communication tools should help people to avoid actions that generate exposure and the establishment of new risk. Therefore, for communication to be effective, maps must address psychological factors—transforming negative emotions like fear and helplessness into positive emotions such as motivation and self-efficacy, which are crucial for encouraging proactive, risk-reducing behaviours

2.3. Storytelling and map-based visual storytelling

2.3.1. Storytelling in science communication

Storytelling, or communication through stories, has long been integral to human society, not only as a way to convey knowledge, traditions, and values across generations but also as a mechanism to shape understanding and social cohesion (Darici, 2023; Gottschall, 2012). According to cognitive psychologist Bruner, (1991) stories function as cognitive frameworks, helping individuals make sense of experiences by organizing information in ways that align with how we naturally perceive the world. He posits that humans are storyteller innately inclined toward narrative reasoning, making storytelling a natural mode of communication. Despite this, the use of storytelling in science communication was controversial for many years. Some scholars considered it unsuitable for conveying scientific findings due to concerns that narratives could compromise objectivity by oversimplifying or distorting complex concepts (Katz, 2013).

During the late 20th century, however, the perception of storytelling in science communication began to shift as researchers observed that stories could enhance comprehension and engagement, especially among non-expert audiences (Morris et al., 2019; Padian, 2018). This shift reflects a broader understanding that effective communication is not solely about accuracy but also about clarity and relatability. Research by (Dahlstrom, 2014) has since shown that storytelling can help bridge the gap between scientific knowledge and public understanding without sacrificing scientific integrity when thoughtfully applied. As Bloomfield & Manktelow, (2021) suggest, using storytelling to communicate climate information to the public does not alter the objectives of the Intergovernmental Panel on Climate Change (IPCC). Instead, it aims to make the information more understandable and personally relevant, helping individuals see how climate science applies to their own lives.

By making communication more engaging, storytelling holds significant potential to make science communication more impactful by influencing the personal beliefs and emotions of the audience (Avraamidou & Osborne, 2009). Decision-making is shaped not only by objective scientific evidence but also by individuals' personal values and feelings (Jones Michael & Anderson Crow, 2017). This underscores the need for scientists to act as storytellers, crafting narratives that emotionally resonate with audiences. By presenting scientific findings through relatable stories, scientists can foster a stronger, more personal connection to the issues, addressing what matters most to people in their daily lives. This approach positions storytelling as a powerful tool in science communication, making complex information more engaging, memorable, and persuasive (Kelly et al., 2014).

Storytelling can be seen as a technique for communicating science through the framework of narrative discourse, which serves as the medium by which stories are conveyed (Austin & Chatman, 1979). Toolan, (2001) describes narratives as sequences of interconnected, non-random events that typically move from one problem to another, culminating in a resolution or conclusion.

This problem-resolution structure reflects how people naturally interpret experiences, making narratives an intuitive means of understanding complex concepts. Norris et al., (2005) than interpret the narratives as a chain or sequence of event that are connected to each other and have an identifiable structure (beginning, middle, end) where events are related temporally. Abbott, (2008) further emphasizes that the chronological arrangement of events that creating a logical order, and coherent flow is a key feature of narratives used as a technique for communicating science. Although scholars may use various terms to describe narrative structure, they consistently emphasize the concept of linearity in conveying information (Figure 2.8).

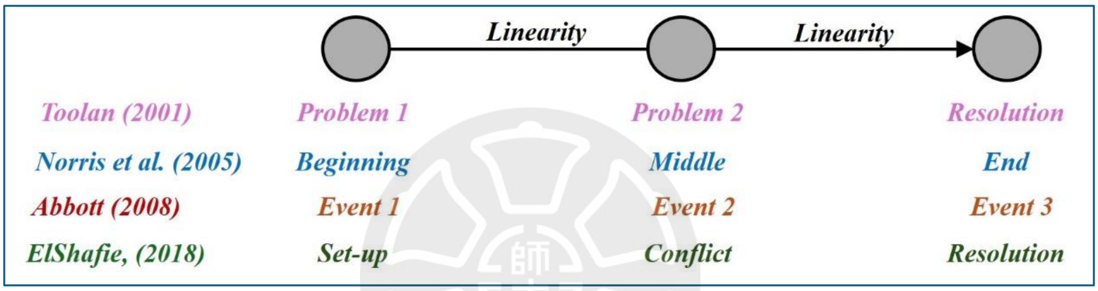


Figure 2.8 Summary on how scholars visualize narrative structures on the science communication.

That sequence structured of narrative also widely known in various disciplines including film, literature and education as the three-act narrative (ElShafie, 2018; T. Huang & Grant, 2020). This structure is typically divided into three distinct phases: Setup, Conflict, and Resolution. Each phase serves a specific purpose in developing the narrative and engaging the audience. In the Setup phase, the narrative introduces the characters, setting, and the initial situation, establishing the context for the story. This phase is critical as it lays the groundwork for the audience's understanding and investment in the narrative. The Conflict phase introduces problem or challenges that the characters must face, creating tension and driving the narrative forward. This phase is essential for maintaining audience engagement, as it often involves dramatic developments that evoke emotional responses. Finally, the Resolution phase provides closure to the narrative, resolving the conflicts introduced earlier and offering a sense of completion. This phase is crucial for delivering the story's message and ensuring that the audience leaves with a clear understanding of the narrative's implications.

2.3.2. Map-based visual storytelling

Storytelling can be expressed through both non-visual formats, such as oral, written, and audio stories, and visual formats, including illustrations, graphics, imagery, videos, and maps (Segel & Heer, 2010). Maps, in particular, are a compelling form of visual storytelling, as they provide a spatial narrative that allows viewers to interpret complex information at a glance. Denil, (2016) discusses this strong connection between maps and story within cartography, noting that maps must fit within a coherent narrative to be fully understandable. Maps also serve as persuasive tools, often guiding readers to adopt a particular interpretation of a situation. However, he also reminds if not all maps tell their stories overtly; sometimes, the narrative is embedded within the design, requiring the user to draw meaning and message through personal interpretation. As such, each map user might derive a unique story from the same map, shaped by their own experiences, background knowledge, and interpretive abilities (Tateosian et al., 2020). This variability underscores the subjective nature of map interpretation, where diverse perspectives can lead to different insights from identical visual information.

To enhance clarity and reduce interpretive differences among map users, cartographers are increasingly adopting approaches that emphasize storytelling structures within cartographic design. This trend, which makes narrative elements more explicit, has been termed in various ways: *narrative cartography* (Caquard & Cartwright, 2014) and *map-based visual storytelling* (Roth, 2021a). These approaches integrate narrative techniques into maps by organizing visual elements to guide users through a structured interpretation. By incorporating clear sequences, contextual cues, and thematic highlights, this narrative-driven cartography aims to lead viewers through a cohesive story, making complex data more accessible and reducing the variability in individual interpretations.

2.3.3. Designing map-based visual storytelling

The article by Roth, (2021) provides one of the most comprehensive discussions on the use of maps as a form of visual storytelling. In his synthesis and review of existing literature, Roth identifies key elements that are essential for designing map-based visual storytelling, discusses various genres that can be employed, and outlines visual-storytelling tropes that enhance narrative clarity and engagement. The primary element in map-based visual storytelling is the concept of narratives structured, which Roth explains as the backbone for the storytelling technique. This structure is often modelled on the linearity structured such as three-act narrative framework, as previously discussed, and is reflected in the map's layout to guide users through the story.

Roth further categorizes visual storytelling into seven genres, each defined by the visual or interactive techniques used to enforce linearity structured of narrative. These range from static stories using framed layouts and annotations to multimedia experiences that employ anchor tags and hyperlinks. The versatility of map-based storytelling allows for a variety of formats, including paper-based, digital, web-enabled, or multimedia maps. Each genre comes with its advantages and limitations, but the choice of genre depends largely on the communication goals and the user's needs.

Additionally, Roth introduces eight visual storytelling tropes, which are design techniques aimed not at representing data directly, but at enhancing the narrative's depth and clarity (Table 2.1). Each trope serves a specific narrative purpose, and they can be incorporated using a range of visual strategies. For example, linear narratives might employ a three-act structure to maintain continuity, while more abstract or metaphorical information might be communicated using cartooning or illustration to make complex data more relatable and easier to understand.

Table 2.1 Visual storytelling tropes proposed by Roth, (2021) and techniques to enhance the narrative's depth and clarity on the map.

Trope	Definition	Visual design technique
Continuity	Unify otherwise disparate visual elements into a logical structure	• Three-act narrative story • Genre pacing: visual layout, display time progressing • Annotation • Interaction: sequencing, panning
Mood	Set a visual tone congruent with the narrative and its elements	• Map element design • Visual style: Colour, Form, Texture • Persuasive style • Marginalia and adornments
Dosing	Reduce overall complexity of story content into straightforward pieces of information	• Linear sequencing • Clear entry point: layout and visual hierarchy • Partitioning: neat lines, negative space
Attention	Emphasize important or unusual information that cannot be missed in the story	• Visual hierarchy / figure-ground • Visual accenting: highlighting, annotation, numbering, changes in map scale
Redundancy	Repeats important or unusual information to develop story themes	• Visual motifs and symbolism • Figures • Visual hierarchy and accenting
Metaphor	Brings together seemingly unrelated concept in a single frame to facilitate understanding of complex narrative elements	• Associative point symbols • Visual juxtaposition: Visual benchmarks, scenarios, cartooning and illustration. • Humour, irony, satire
Voice	Embeds situated experiences, opinions, and value into the visual story to clarify meaning	• Designer voice • Character voice • Audience voice • Narration: audio and audiovisual

2.4. Map's effectiveness controlling factors

In cartography, map usability is a critical concept that represent the quality of cartographic design as no map is effective unless it clearly and intuitively communicates its intended message to users, ensuring that the information provided is accessible and valuable for understanding complex spatial patterns or facilitating decision-making (Fairbairn et al., 2021; Tyner, 2014). Map usability refers to how easy users can interact with a map to fulfil specific tasks and understand its intended purpose (Roth et al., 2017). Usability encompasses not only the clarity of the map's content but also its ability to intuitively guide users towards achieving their goals. A higher level of usability means that users can more readily grasp the map's objective (Unrau & Kray, 2019).

Maps with high usability also demonstrate a good cartographic quality, as their designs are easily recognized, understood, and utilized by users (Burian et al., 2018). This indicates that mapmakers have effectively chosen visual elements—such as symbols, colours, labels, and pictures—that not only informative but also align with users' needs. Informative visualizations help reduce confusion and cognitive load, enabling users to interact with the map confidently and feel satisfied with them. The importance of usability is particularly evident in high-stakes contexts, such as disaster communication or urban planning, where well-designed maps are crucial for informed decision-making (Bang-Kittilsen & Midtbø, 2024) . High-quality cartographic design ensures that maps are accessible and meaningful to both experts and non-experts, highlighting the value of usability as a core attribute in supporting effective communication.

In the context of maps for landslide risk communication, designing a map that can effectively influence user perception and encourage proactive actions in risk reduction or management is also crucial. Maps serve not only as informational tools but also as persuasive instruments that can shape how users understand and respond to hazards. (Dransch et al., 2010) highlighted that users' perceptions of a map's efficacy in disaster risk reduction efforts play a critical role in determining whether the map will be utilized in practice. If users perceive the map as clear, reliable, and relevant to their needs, they are more likely to trust and act upon the information it conveys. Therefore, designing a map with the intent to positively influence user perception becomes an essential factor in ensuring its success as a tool for landslide risk communication, ultimately aiding in more effective risk reduction and management efforts.

2.5. Summary and research gaps

Based on the literature review, numerous studies have demonstrated the usefulness of detailed geomorphological mapping in landslide research. According to Davies et al., (2021), geomorphological maps play at least four critical roles in efforts to reduce landslide risk: (1) illustrating the distribution of landslides, (2) understanding their causative factors, (3) predicting future hazard scenarios and their impacts, and (4) designing mitigation actions to reduce risk. A deeper analysis reveals that the first two roles enable us to understand where, why, and how landslides occur. Communicating this information to the community can potentially enhance their awareness and understanding of landslide dangers. Moreover, by integrating the distribution of elements at risk—such as settlements, road networks, agricultural land, and other human assets—with landslide hazard information on geomorphological maps, we can estimate how significant the impact of a landslide event might be. This information is invaluable for identifying areas that are more vulnerable to disasters. Ultimately, understanding the spatial distribution of elements at risk and potential hazards facilitates the design of more detailed disaster risk reduction efforts, including determining appropriate mitigation strategies and prioritizing areas for intervention.

While geomorphological maps are widely acknowledged within the geoscience community for their value in landslide risk reduction, their potential as risk communication tools remains largely unexplored by other non-geoscientist stakeholders engaged in these efforts. A literature review by Pratiwi et al., (2023) highlights that geomorphological maps are far less prevalent in community-based landslide disaster management programs compared to geological maps, slope maps, and landslide inventory maps. Generally, communities rely on these maps to identify landslide locations and assess the physical characteristics of landslide-prone areas. For understanding hazards and risks, however, they tend to use zoning maps that employ ordinal classifications. This preference reveals a gap in the use of geomorphological maps, even though they have the potential to convey essential insights into the nature of landslides, providing a deeper understanding of landslide hazards, their possible impacts, and mitigation strategies design.

In fact, landslide hazard zoning maps are simplified derivatives of geomorphological maps, created specifically for non-geoscientists engaged in disaster risk reduction. Griffiths & Abraham, (2008b) explained that this approach was developed to make the complex information in large-scale geomorphological maps accessible to non-expert users. They describe how detailed geomorphological maps, built from slope morphology interpretations, serve as the foundation for assessments that categorize landslide hazards into four classes (Figure 2.9).

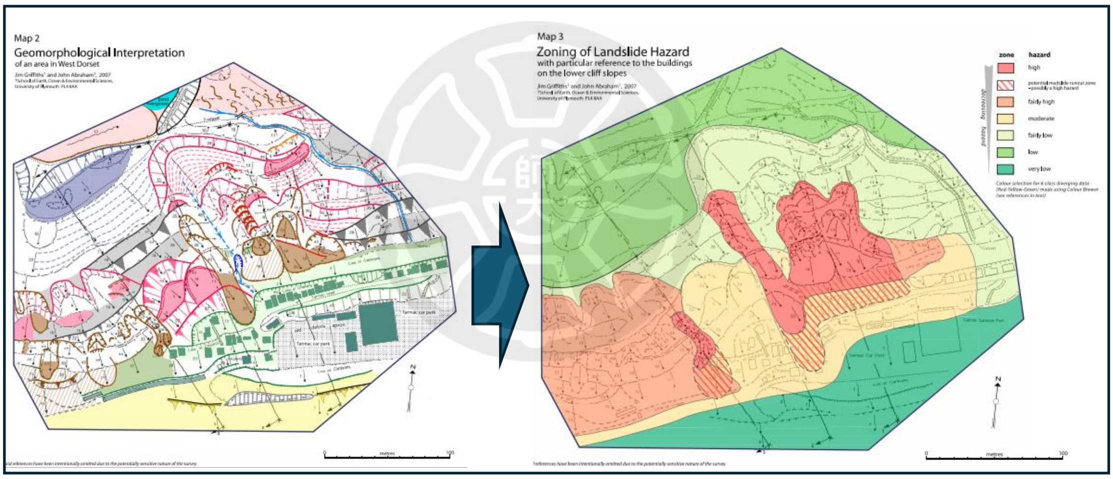


Figure 2.9 Illustration in simplifying basic geomorphological map into zoning of landslide hazard which hinder many landform information (Griffiths & Abraham, 2008a).

However, landslide hazard maps often come at a cost: classifying areas according to hazard level can make people underestimate areas with lower levels. This assumption may not hold true in the face of changing environmental conditions, such as climate change, which can alter the dynamics of landslide hazards (Lin et al., 2022). Consequently, if the public relies on outdated or inaccurate maps, they may underestimate the risks associated with landslides, leading to inadequate preparedness measures. Another critical issue is the variability in the methodologies employed to create these maps. Different studies may use diverse approaches, such as statistical methods, fuzzy logic, or heuristic methods, which can produce varying results for the same geographical area (Chingkhei et al., 2013; Vanlalnunzira, 2024). This inconsistency can confuse the public, as they may encounter multiple maps with different hazard classifications for the same location, undermining trust in the information provided (Henstra et al., 2019; Pratiwi et al., 2023). Moreover, essential landform features, including landslides, are sometimes omitted or even removed entirely from the final map. This can hinder the full conveyance of geomorphological maps' value and diminish their visibility and perceived importance in the public eye.

In 2023 Shen et al. (2023) proposed a user-centred mapping design approach to make geomorphological maps more accessible as hazard communication tools for non-experts in geomorphology. This approach emphasizes displaying key landform features crucial for understanding environmental conditions, such as floodplains, fluvial terraces, river and gully channels, as well as hazard-prone features like rock falls, debris flows, and potential large-scale landslides. In the map design process, they actively involved users to gather feedback, enhancing readability and ensuring that the final map effectively meets user needs. This participatory approach aims to improve map accessibility and relevance for a broader audience in hazard communication.

The user-centred geomorphological map developed by Shen et al. (2023) represents a significant advancement in making geomorphological maps more accessible to a broader audience. However, their research primarily focuses on optimizing design to align with user needs and improving readability. It does not delve into how intuitively users can interpret the map’s messages, the extent to which the map proves beneficial, or users' responses after engaging with it. Understanding these aspects is essential for evaluating the map's effectiveness as a communication tool, as they reveal whether the map truly enhances users' comprehension of hazard information and supports informed decision-making.

On one side, visual story-based map design is gaining traction among geoscientists as an effective method for conveying complex knowledge to the public. For instance, the visual storytelling approach has been used to enhance the functionality of static flood inundation maps in disaster management (de Bruijn et al., 2016). Previous research also incorporated narrative elements into maps to support government officials in understanding earthquake risk scenarios proposed by scientists (Rodgers et al., 2020) (Figure 2.10). In another example, visual story maps have been applied to sea level rise (SLR) scenario maps, providing the public with insights into potential damages in coastal cities (Vollstedt et al., 2021).

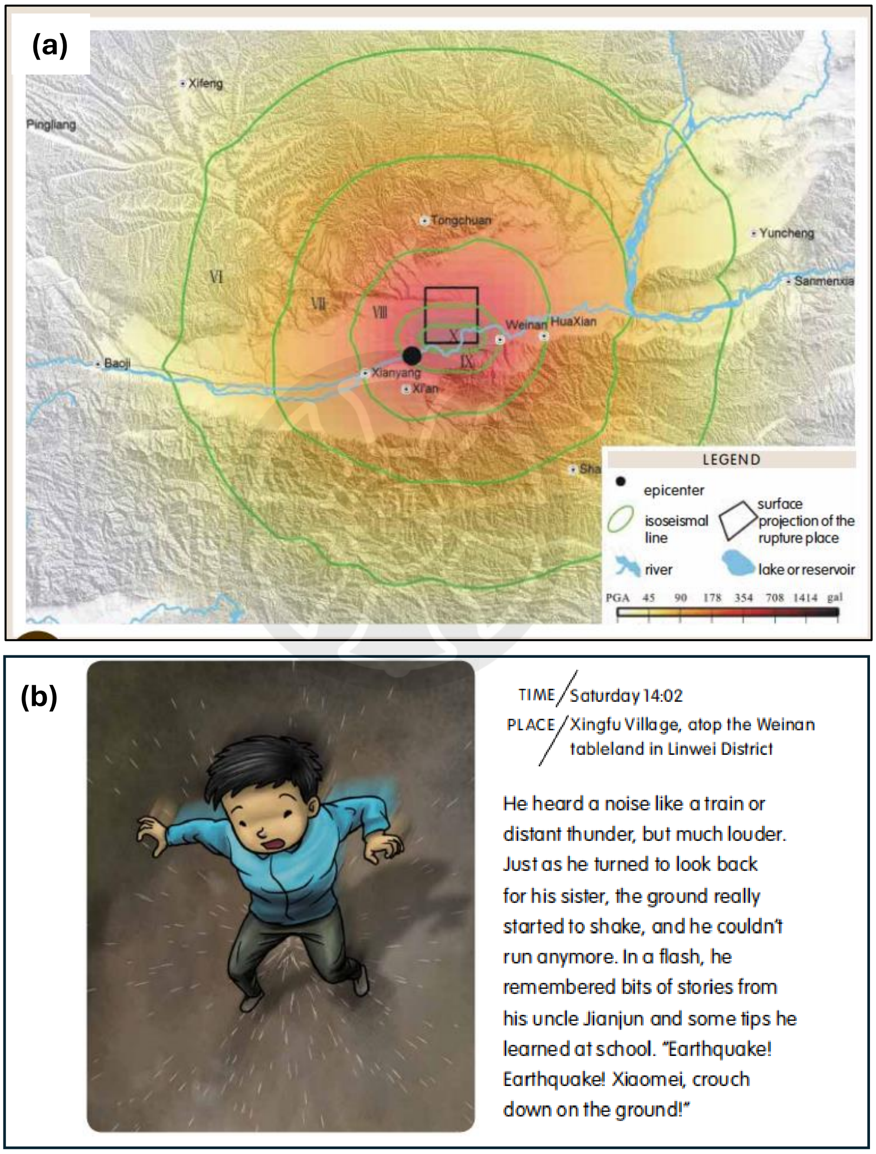


Figure 2.10 Map-based visual storytelling to communicate the M7 1568 Shaanxi Gaoling earthquake scenario to the government official created by Rodgers et al. (2020). a) The visualization of shaking intensity map. b) An illustration a comic and story paragraph from the narrative version of the map.

However, research on map-based visual storytelling to create effective landslide risk communication tools for non-expert users is still limited. Moreover, the extent to which this integration can influence map usability and user perception has not been thoroughly explored. Therefore, this study aims to fill this gap by proposing a visual story-based geomorphological map design for effective landslide risk communication. Beyond introducing the map design process, this research evaluates the effectiveness of the map through user testing, providing insights into its practical impact. Finally, strategies for future design improvements are also outlined to support the ongoing development of effective communication tools in landslide risk management.

Chapter 3 – Methodology

3.1. Research design

Based on the literature synthesis, geomorphological maps are acknowledged not only as valuable scientific tools but also as promising instruments for landslide risk communication for non-expert user. By offering detailed visual representations of Earth's surface forms, geomorphological maps can present more vivid element of hazards and risks, fostering greater community awareness and promoting more effective risk management practices. Therefore, geomorphological maps hold potential to bridge the communication gap in landslide hazard understanding, providing essential information that supports disaster risk reduction efforts.

Despite their advantages, existing approaches to popularizing geomorphological maps—such as simplifying them into landslide zoning maps (hazard or risk maps)—face significant limitations. These zoning maps typically provide only generalized information about the level of hazard or risk, without addressing critical questions such as why certain areas are more at risk, where specific landslide hazards are located, or the magnitude of potential threats and impacts. Consequently, these maps fall short as effective tools for landslide risk communication. They fail to empower users to design targeted mitigation strategies or inspire proactive engagement in disaster risk reduction efforts

Instead of simplifying geomorphological maps into zoning maps, this study aims to design a map that preserves critical landform information, offering deeper insights into landslide hazards and risks. The data presented in the geomorphological map for non-expert users in this research is derived from large-scale Basic Geomorphological Maps—maps created specifically for the geoscience and geomorphology community—ensuring a high level of credibility and accuracy. The complex information in these basic maps is selectively filtered, generalized, or supplemented to meet the objectives of the new map. Given its foundation in basic geomorphological mapping, the map designed for non-expert users in this study is referred to as the "Derivative Geomorphological Map."

However, researcher acknowledge that introducing geomorphological data for non-experts is a challenging task, largely due to the specialized and complex nature of geoscience data, which is often unfamiliar to lay users. This lack of geoscientific knowledge can make it difficult for users to interpret detailed geomorphological information presented in maps. Additionally, the inherent complexity of this data can render maps difficult to use, increasing the likelihood of misinterpretation or confusion. This can negatively impact users' perceptions of the map's value and decrease their willingness to engage.

Therefore, this research aims to create a new model for popularizing geomorphological maps as effective tools for landslide risk communication by integrating them with a visual storytelling approach. This model was then named Visual Story-Based Geomorphological Map (VSGM) and developed in Magelang County, Central of Java, representing one of the most landslide hazardous area in Indonesia.

3.1.1. Storytelling in the context of VSGM

Any maps, including derivative geomorphological maps, function as visual media that communicate information primarily through graphics. Unlike storytelling, which conveys information in a definite sequence, maps deliver visual impressions simultaneously rather than in a linear order (Robinson et al., 1995). This means that mapmakers cannot structure their communication sequentially, as they would in speech or writing. Instead, they must approach the map as an integrated whole, carefully considering how all elements work together to convey the intended message effectively.

When users view a map, their brains process the information perceptually through their sense of sight. However, various factors—such as educational background, map-reading skills, emotions, and focus—can influence human perception, leading to differing interpretations of the same map. These variations are even more pronounced among non-expert users who lack prior knowledge of the information being conveyed. Such discrepancies in interpretation are a significant concern for mapmakers, as they can result in users receiving inconsistent or even incorrect messages, undermining the map's effectiveness as a communication tool.

Storytelling in the context of VSGM serves as a way to enhance the delivery of information presented on the Derivative Geomorphological Map which is created from Basic Geomorphological Map to users in an organized and sequential manner. Instead of providing a traditional booklet, which is commonly used to offer detailed explanations of map content, this research introduces two storytelling-based supporting media: comics and instruction sheets (Figure 3.1). These supplementary tools aim to guide non-expert users in reading and understanding the map's messages (in this case, the DGM) in a logical sequence (Figure 3.2a). By using these storytelling-based visual aids, the study seeks to prevent users from interpreting the DGM in a disorganized manner (Figure 3.2b), which could lead to inconsistencies in perception and varying levels of information understanding among users.

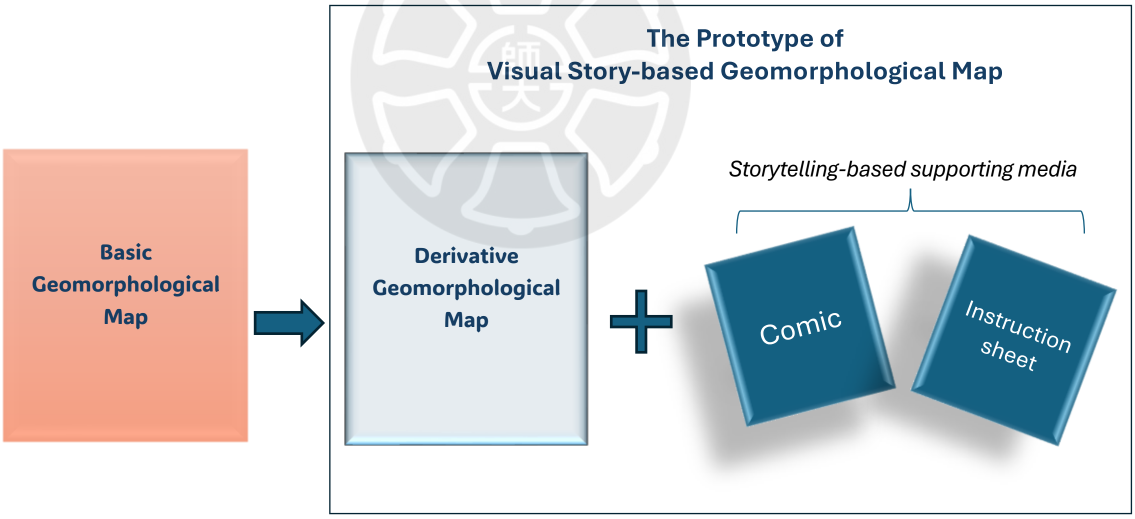


Figure 3.1 Illustration of VSGM prototype that consists of a derivative geomorphological map, a comic and an instruction sheet.

An illustrated comic story is provided to map users before they engage with the Derivative Geomorphological Map (DGM). The comic is designed to introduce the definition and purpose of geomorphological maps in an engaging and accessible way, using everyday language tailored for non-expert users. By incorporating relatable characters, dialogues, and scenarios, the comic transforms complex geomorphological concepts into a compelling narrative that connects with users on a personal level and presents information sequentially. This approach not only simplifies the technical information depicted on the map but also helps users better understand and retain the map's core messages.

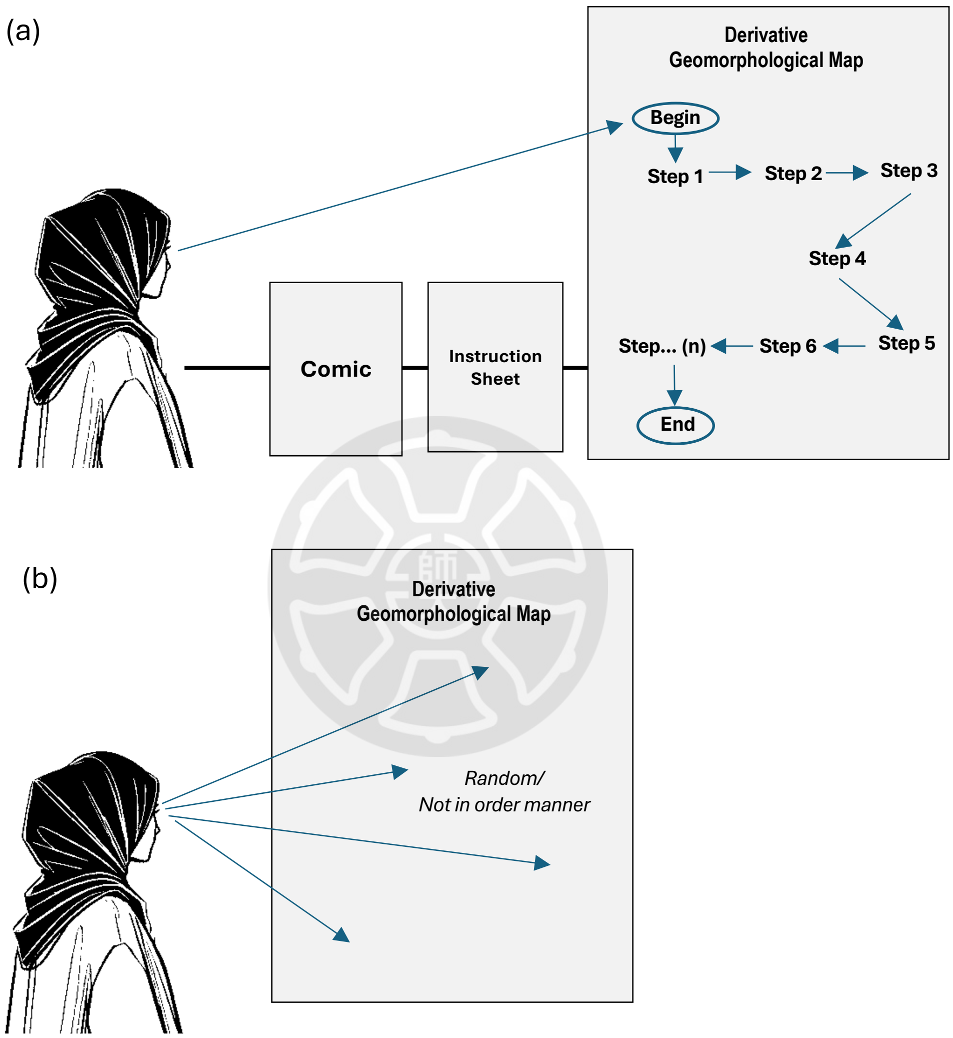


Figure 3.2 Comparison of user interaction and understanding of maps. a) Storytelling-based supporting media, such as comics and instruction sheets, guide users to interpret maps in a structured and sequential manner. b) Traditional maps, in contrast, are often used and understood in a random or non-linear way, lacking an organized approach.

The instruction sheet acts as a vital supporting tool that enhances the storytelling aspects of the Derivative Geomorphological Map (DGM). By providing step-by-step guidance, it helps users navigate the map effectively and uncover its intended messages with ease. Functioning like a script, the instruction sheet positions map users as participants in a narrative, guiding them on where to begin and how to proceed through the map's content. By establishing a clear storyline, the instruction sheet ensures that users—regardless of their diverse backgrounds or varying map-reading skills—can achieve a consistent understanding and perception of the map's key messages.

3.1.2. Risk communication in the context of VSGM

This research presents the development of the Visual Story-based Geomorphological Map (VSGM) as an innovative channel or media (Figure 3.3) to risk communication, utilizing large-scale geomorphological data to effectively convey landslide risk to disaster educators without a geoscience background. By transforming a geomorphological map originally intended for expert use into an accessible, narrative-driven visual tool, the VSGM bridges the knowledge gap between technical geomorphological insights and non-specialist understanding. The VSGM underscores the critical role of large-scale geomorphological mapping in enhancing localized spatial awareness of hazards and risks, thereby enabling the implementation of site-specific and effective disaster risk reduction (DRR) strategies.

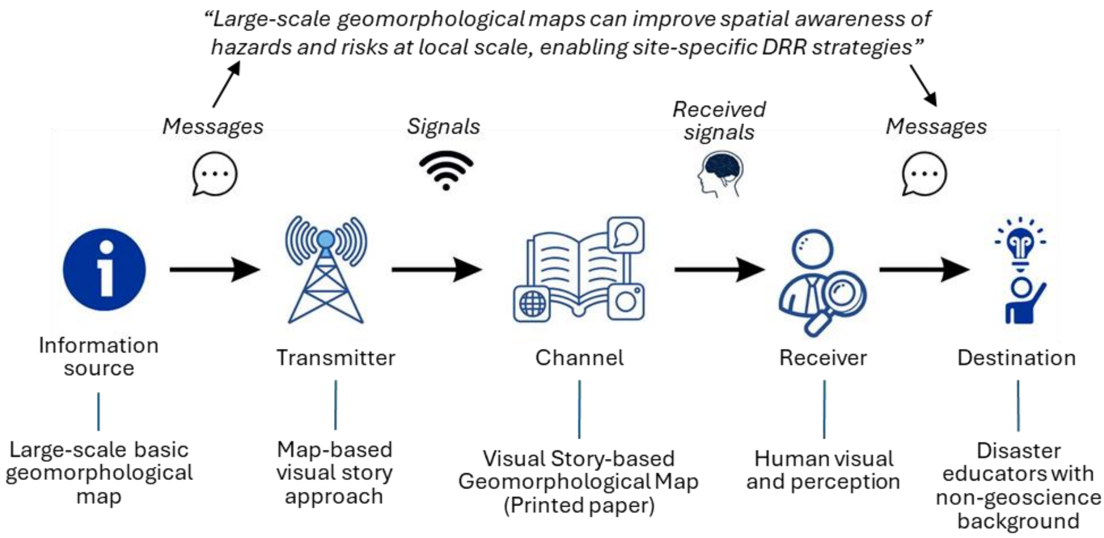


Figure 3.3 The position of VSGM in the communication system

The framework of the Visual Story-based Geomorphological Map (VSGM) as a landslide risk communication tool is illustrated in Figure 3.4. The VSGM is developed using information from large-scale geomorphological maps to achieve two primary communication objectives: **substantive purposes**, which pertain to the knowledge conveyed to users, and **affective purposes**, which aim to influence users' feelings and perceptions (Robinson et al., 1995).

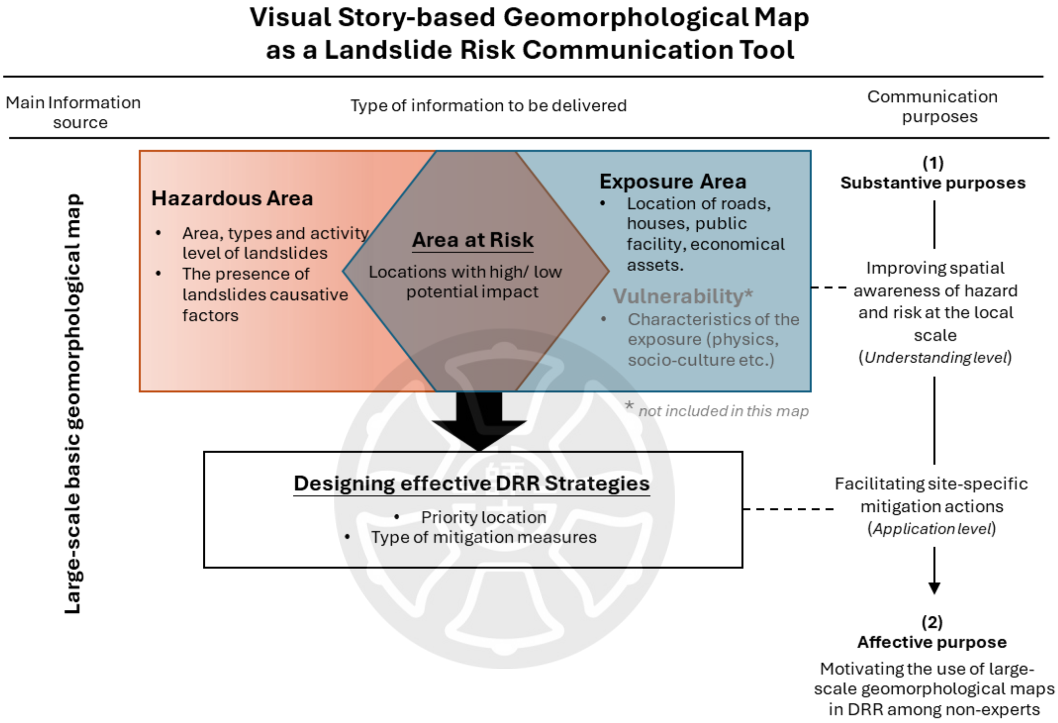


Figure 3.4 Risk communication framework in the context of VSGM

The primary objective of the Visual Story-based Geomorphological Map (VSGM) is to enhance spatial awareness of hazards and risks at the local level. By effectively depicting small and recently formed landforms, large-scale geomorphological mapping serves as a critical tool in landslide risk reduction. First, it facilitates detailed identification of the location and area of post-landslide events while providing insights into key characteristics, such as landslide type and activity status (active or inactive). Additionally, it enables the identification of causal factors, distinguishing between natural triggers and those induced by human activity. These functions are integral to delineating landslide-hazardous areas; for instance, regions surrounding active landslides present higher reactivation potential, while slopes adjacent to rivers exhibit increased susceptibility due to erosional forces linked to previous events.

Large-scale geomorphological mapping also extends its utility to the identification of anthropogenic landforms, including infrastructure such as buildings, road networks, and slope modifications, which represent elements of exposure in landslide risk assessments. By integrating these features with hazardous zones, the mapping process assumes a critical role in identifying areas of heightened risk, particularly those with significant potential for loss in the event of future landslide occurrences.

The second substantive objective of the Visual Story-based Geomorphological Map (VSGM) is to assist users in developing site-specific mitigation measures. Once at-risk areas are identified, large-scale landslide mapping serves as a valuable reference for designing targeted mitigation strategies. By providing enhanced spatial insights into hazardous and high-risk areas, the VSGM equips users with the necessary information to recommend appropriate mitigation measures and prioritize locations for intervention. This applicative function plays a crucial role in improving the effectiveness of disaster risk reduction efforts by ensuring mitigation resources are allocated to the most critical areas.

Beyond its substantive objectives, the VSGM is designed with a broader goal: to promote the use of large-scale geomorphological maps among non-experts involved in DRR. By incorporating extensive scientific data—specifically geomorphological information—the VSGM seeks to maximize the benefits experienced by its users. This design goes beyond merely enhancing understanding of landslide hazards and risks; it also encourages users to think critically about how the map can be applied to develop effective mitigation strategies for their specific local contexts. By demonstrating its practical value and versatility, the VSGM aims to familiarize non-expert users with the utility of geomorphological maps, fostering greater adoption and use of these tools to support their roles as disaster communicators.

3.1.3. Research framework

This research framework builds upon the development of the Visual Story-based Geomorphological Map (VSGM), which integrates a Derivative Geomorphological Map with storytelling techniques through comic and instruction sheet (Figure 3.5). To evaluate the VSGM's effectiveness as a landslide risk communication tool, the study employs an empirical approach focusing on two main objectives: substantive and affective (see Figure 3.4). Specifically, the research examines whether the VSGM achieves its intended communication goals through a dual evaluation of cartographic design quality and user perceptions.

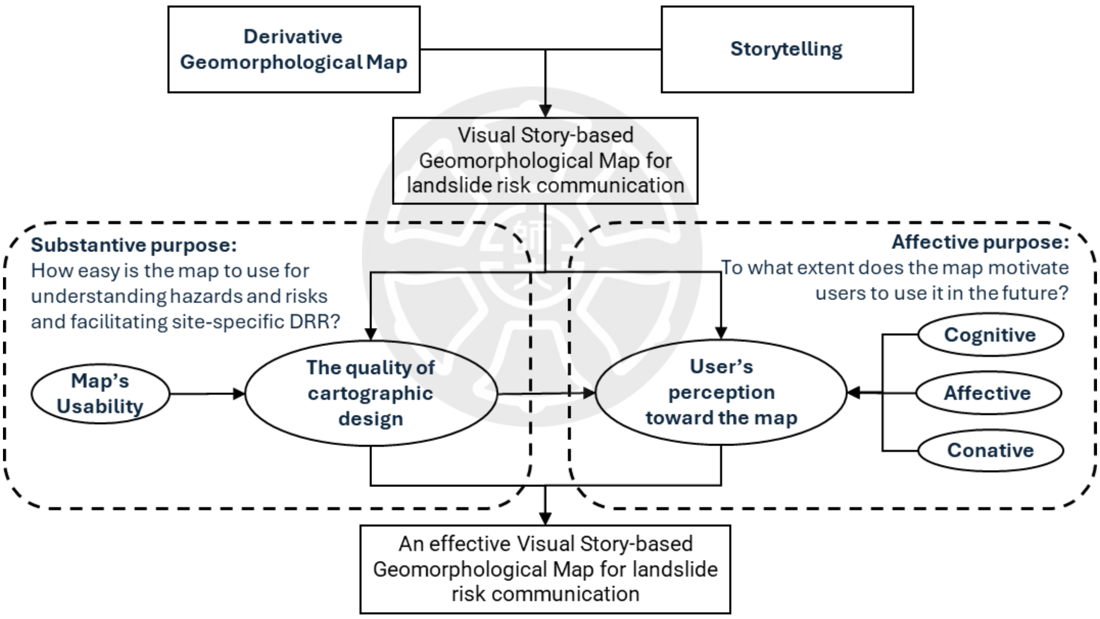


Figure 3.5 The research framework

The quality of the cartographic design is assessed through a usability evaluation, which measures how effectively users can interact with the VSGM to complete tasks relevant to landslide risk reduction. This evaluation is crucial to determine whether the map's design is user-friendly and capable of conveying complex information in an accessible manner. By aligning usability assessment with the functional role of geomorphological maps in disaster risk reduction (DRR), the study highlights the importance of effective design in achieving the VSGM's substantive objectives.

The second evaluation focuses on user perceptions, examining how users respond to the VSGM after engaging with it. This assessment explores the extent to which the map inspires and motivates users to integrate geomorphological maps into DRR initiatives. The analysis of user perception is guided by the Hierarchy of Effects Model (HOEM), a framework that explains how communication influences human behaviour. HOEM measures the progression of effects from awareness to action, offering insights into how information can shape user motivation (Wijaya, 2012). While widely applied in advertising to predict consumer behaviour in response to campaigns (Craig et al., 2015), HOEM has also been utilized in educational research, such as analysing the learning experience from digital game design (C. H. Wang et al., 2019). By leveraging this model, the study provides a deeper understanding of the affective impact of the VSGM, thereby evaluating its broader potential as a tool for fostering proactive engagement in DRR efforts.

The theory of HOEM stated that the audience responds to the message in a very ordered way, firstly cognitively, then affectively, and finally conatively (Wijaya, 2012). Cognitive dimension is defined as mental activity as reflected in people knowledge and thought about aspects in their world; affective dimension is related to the people feeling and emotion toward a phenomenon; conative dimension is typically an intention force to perform a behaviour or action. In the context of this research, the cognitive dimension describes the extent to which users are aware about the role of geomorphological maps in reducing the risk of landslides. The affective dimension shows the map user's feeling about the urgency of geomorphological information in understanding landslide hazards and risks. Finally, the conative dimension describes the user's willingness to use geomorphological maps as their instrument in communicating landslide risk with the public.

As this study represents a pioneering effort in developing an innovative model for disaster risk communication tools, implementing strategic approaches for future development is essential to enhance the VSGM's effectiveness and scalability. Insights obtained from the evaluation processes—including usability testing and user perception assessments—provide a valuable foundation for this endeavour. The findings reveal both the strengths of the VSGM and areas requiring improvement to better meet the needs of non-expert users.

3.2. Study area and the construction of basic geomorphological map

Situated along the boundary of the Eurasian and Indian tectonic plates, Indonesia boasts an extensive volcanic landscape spanning the islands of Sumatra, Java, Bali, and Nusa Tenggara. Volcanic activity from the Tertiary to Quaternary periods has shaped this landscape, resulting in deposits ranging from coarse pyroclastic materials to thick layers of volcanic ash. In ancient or dormant volcanic regions, these pyroclastic materials have undergone significant alteration and weathering, forming deep layers of clay. The swelling and shrinking properties of clay soils make these areas particularly susceptible to landslides during the rainy season, with displaced material primarily composed of earth. These geomorphological conditions render much of Indonesia's volcanic landscape highly prone to landslides, characterized by post-volcanic mass wasting processes.

In this research, the southern flank of the Sumbing Volcanic Landscape was selected as the study area because it exemplifies a volcanic region prone to post-volcanic mass wasting processes in Indonesia. Additionally, the area's fertile soil supports a dense population, making it not only hazardous but also highly at risk of landslides. The following description and discussion about the study area and the construction of large-scale basic geomorphological map used as the information source of VSGM refers to the newly published article by researcher entitled "Understanding the nature of landslides through detailed geomorphological mapping on the Sumbing Volcanic Landscape, Java Island, Indonesia" (Pratiwi et al., 2024)

The study area is located at Margoyoso Village in Magelang Regency, Central Java Province (Figure 3.6a). Geographically, this area lies in the foothills of Mount Sumbing, a dormant volcano, and is bordered by the Tertiary volcanic landscapes of the Menoreh Mountains and Serayu Range (Figure 3.6b). Aerial photographs reveal that the hilly slopes are covered by vegetation and settlements, while the valleys are predominantly used as paddy fields (Figure 3.6c). Thick clay soil layers, which play a significant role in controlling landslides, are evident in outcrops within areas affected by large rotational landslides (Figure 3.6d).

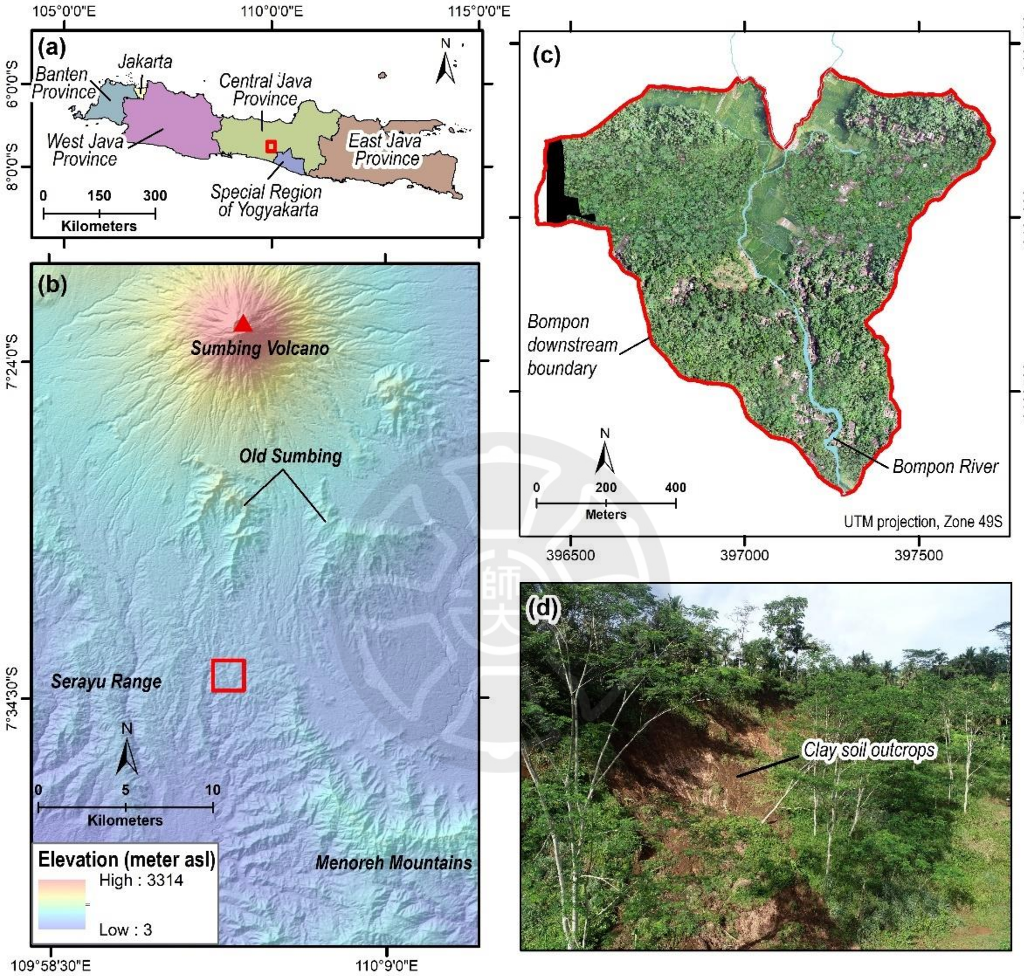


Figure 3.6 Mapping area of VSGM prototype (red square). a) Location of Central Java Province, Indonesia. b) The mapping area located in the southern flank of Sumbing Volcanic Landscape surrounded by Old Sumbing mountains, Menoreh mountains and Serayu range.c) land cover of the mapping area seen from the aerial photograph. d) Clay soil outcrops in the mapping area seen from the landslide scarp. (Source: Pratiwi et al., 2023)

The large-scale geomorphological map was created using high-resolution spatial data, including LiDAR Digital Terrain Models (DTMs), Global Navigation Satellite System (GNSS) data, multi-year aerial photography, and Unmanned Aerial Vehicle (UAV) imagery, along with extensive field surveys.

The resulting geomorphological map provides detailed information on the distribution and characteristics—such as morphology, type, and activity levels—of gravity-driven landforms and other features related to mass movement processes at a scale of 1:2,500. The final version of this 1:2,500 scale geomorphological map can be found in the supplementary data 1 (see supplementary folder).

The results and discussion of large-scale geomorphological map in Pratiwi et al., (2024) revealed several critical findings that important to be communicated to stakeholders involved in disaster risk reduction through the VSGM. These findings are as follows:

1) **Landslide distribution and activity levels:** The majority of the hilly areas in the study region consist of relict landslides that have largely stabilized over time. However, recent landslides with varying activity levels—categorized as active, dormant, and suspended—have been identified in several locations, each exhibiting different dimensions and characteristics.
2) **Landslide types:** Due to the presence of very thick clay layers, the most common types of landslides in the study area are rotational slides and translational slides.
3) **Landslide causative factors:** Landslides in the study area are triggered by both natural and human-induced factors. Natural triggers include high-intensity rainfall and the erosion of slope toes caused by river or gully flows. Human-induced triggers primarily involve slope cutting activities on relict landslide scarps, often exceeding heights of 5 meters.
4) **Reactivation potential of landslides**. According to the qualitative assessment stated on the article's discussion, the relict landslides in the study area tend to exhibit characteristics associated with lover reactivation potential because they have non-apparent landslide boundaries, dense and uniform vegetation, gully formation on the scarp or body, and gentler slopes at the landslide's scarp and body. In contrast, the recent landslides exhibit morphological features that suggest a high reactivation potential. These features include apparent landslide boundaries, sparse or abnormal vegetation, soil cracks at the crown or scarp, and steep scarps and bodies.

5) **Determination of landslide hazardous areas:** The identification of landslide hazardous areas is based on an analysis of reactivation potential and causative factors. In the research area, these hazardous zones include areas surrounding recent landslides—whether active, dormant, or suspended—due to their higher likelihood of reactivation. Additionally, slopes along riverbanks, gully walls, and areas with slope cuts exceeding 5 meters are also classified as hazardous, as they are associated with key landslide causative factors.

6) **Determination of high-risk landslide areas and site-specific disaster mitigation action:** Once the boundaries of landslide hazardous areas are delineated, high-risk areas can be identified by incorporating information on elements at risk or exposure factors, such as settlements, road networks, or public facilities, into the geomorphological map. Areas with a high concentration of settlements or critical infrastructure within the hazardous zones are classified as high-risk and require prioritization for disaster mitigation efforts. Conversely, areas with fewer or no such elements at risk are considered lower priority for mitigation planning.

3.3. Research flow chart

This research was conducted through a multi-stage experimental process. The first stage focused on designing a VSGM prototype that is easily understood by the disaster communicators who are not geomorphologist. The second stage concentrated on evaluating the usability of the VSGM and exploring how the design influences users' perceptions of the role of geomorphological maps in the context of landslide risk reduction. The third stage concludes with recommendations for further developing the visual storytelling approach to enhance the efficacy and effectiveness of geomorphological maps as landslip risk communication in Indonesia and wider high-risk regions. The research flow is presented sequentially in Figure 3.7 and elaborated upon in the following subsections.

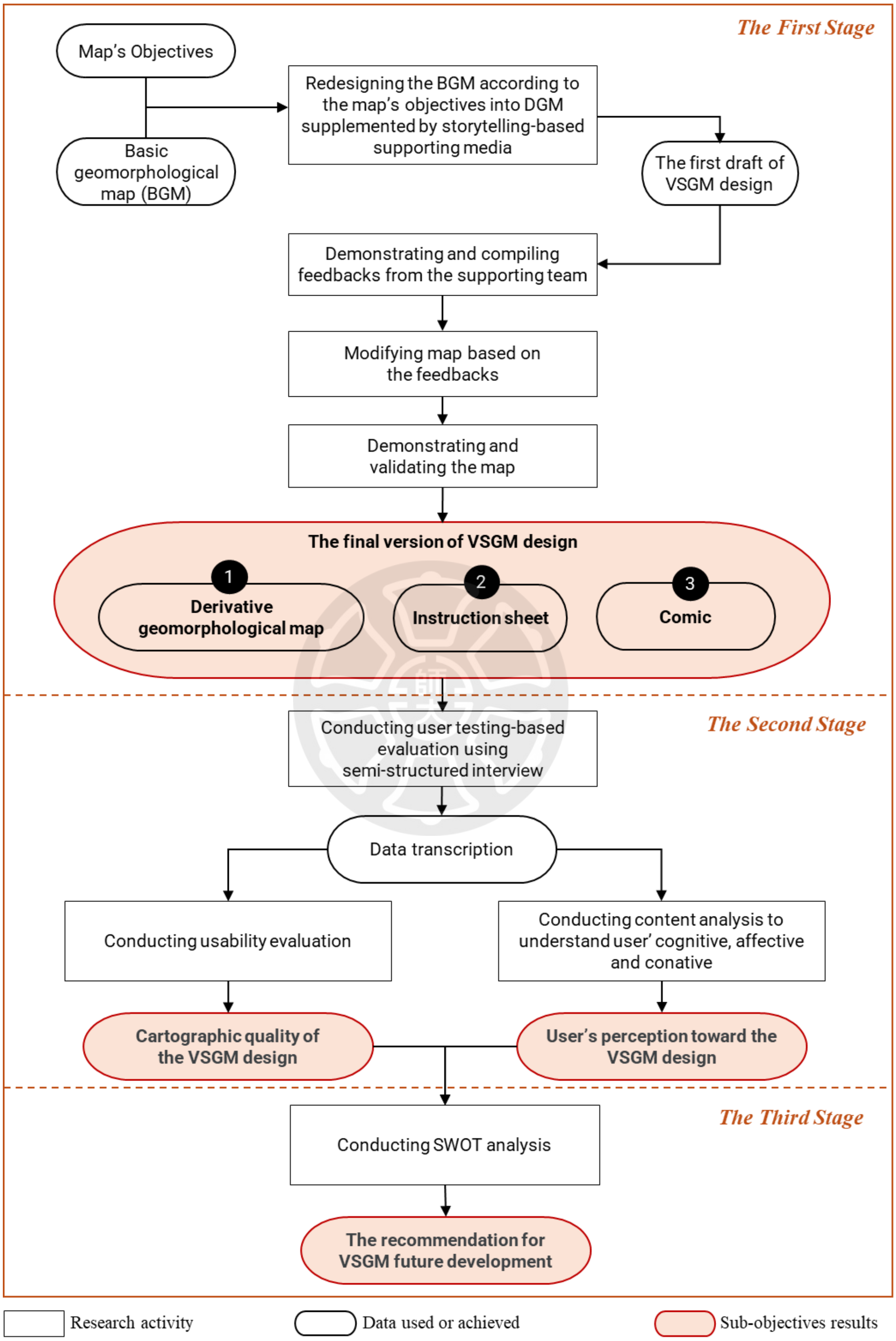


Figure 3.7 Research flow chart

3.4. Creating the prototype of VSGM design

The creation of the VSGM prototype was conducted using co-production techniques. Co-production, as defined by Beier et al., (2017), involves the collaborative engagement of scientists, managers, and other stakeholders to create effective approaches for translating scientific discoveries into practical applications. In the field of map-making process, this approach has been widely adopted by cartographers to incorporate input from diverse experts and end users, ensuring high-quality design that meets user needs (Driedger et al., 2024; Vollstedt et al., 2021). In this study, co-production is expected to yield similar benefits by enhancing the quality of the VSGM design and ensuring that the map's objectives align with the needs of the target users.

In this research, two teams were involved in the co-production process. The first team, referred to as the main team, consisted of myself as the PhD student leading the research, along with my supervisor. Together, we represent a mix of early-career and senior researchers with expertise in geomorphology, disaster management, and environmental education. The main team was responsible to create the first draft of VSGM design. The second team, known as the supporting team, comprised five professionals with expertise in geomorphology, cartography, disaster management, geography education, learning media, and graphic illustration. Additionally, two targeted map users, both non-geoscientists working as disaster communicators in local government agencies, contributed to the design process. The supporting team was responsible to give feedback from the first draft of VSGM design and eventually to produce the final version of VSGM.

3.4.1. The first draft of VSGM design

The VSGM prototype comprises a static Derivative Geomorphological Map (DGM) and two storytelling-based supplementary materials: instruction sheets and comics. The static Derivative Geomorphological Map was developed by modifying the Basic Geomorphological Map (BGM) published by Pratiwi et al., (2024) to align with the new map objectives and context. Similar to the process of creating map designs in general, the DGM was developed by considering key aspects that control map design: **purpose, audience, environment, and map presentation** (Robinson et al., 1995; Tyner, 2014). Defining these four controlling aspects provides context for the VSGM and clarifies the situation in which it is intended to be used.

The comic was designed to give an introduction to the user using a narrative structure approach about what geomorphological maps are and why users need to know it. The comic storyline was developed using the concept of continuity and linearity in storytelling, represented in this study by a three-act narrative structure. The three main elements—set-up, conflict, and resolution—served as a framework for guiding the researchers in crafting the storyline from the beginning to the end.

The instruction sheet is an essential component of the storytelling-based supporting media, serving as a comprehensive guide to help users effectively read and understand the purpose of the DGM. It has been carefully designed to provide a clear, step-by-step pathway that users can follow, ensuring they can engage with the map intuitively and meaningfully from start to finish. Acting as more than just a set of directions, the instruction sheet functions like a script, empowering users to step into the role of an active participant. It encourages them to explore the DGM in a way that resonates with their own experiences, enabling them to construct their own narrative and better grasp the map's significance.

3.4.2. The final version of VSGM design

After the first draft of VSGM design was established, the main team conducted individual meetings with each member of the supporting team. the meetings aimed at demonstrating the design and gathering feedback from the supporting team. These meetings were held one-on-one with each supporting team member, based on their time availability. There are seven members in total in the supporting team consisting of 5 professionals from different fields and 2 map users (Table 3.1).

The consultation process with the supporting team involved addressing two key questions: 1) Do the objectives of the VSGM align with user needs? Please provide reasoning for your answer; and 2) What aspects of the VSGM require improvement? Following the meetings, the main team modified and refined the VSGM based on the feedback. The revised draft of the VSGM design was then presented to the supporting team during a second round of meetings. The purpose of these meetings was to confirm that the suggested improvements had been implemented and to reach a mutual agreement among all team members that the VSGM design was now suitable for its intended purpose. Once consensus was achieved during the second meeting, the final version of the VSGM was produced. This final version was subsequently used to conduct user testing-based evaluation for the next stage of this research.

Table 3.1 List of the supporting team in the co-production of VSGM

Team member	Institution	Position on the supporting team
Expert 1	Center of Land Resources Development. Universitas Gadjah Mada.	Geomorphology and cartography Expert
Expert 2	Research Center for Disaster. Universitas Gadjah Mada.	Disaster management expert
Expert 3	Department of Geography Education. Universitas Muhammadiyah Surakarta.	Disaster education expert
Expert 4	Resilience Development Initiative of Indonesia.	Learning media expert
Expert 5	Freelance graphic illustrator	Graphic Illustration expert
Map User 1	Division of Prevention and Preparedness. Badan Penanggulangan Bencana Daerah.	The targeted map user 1
Map User 2	Division of Prevention and Preparedness. Badan Penanggulangan Bencana Daerah.	The targeted map user 2

3.5. Conducting user testing-based evaluation

After completing the final version of the VSGM, a user testing-based evaluation was conducted to analyse its usability as well as users' cognitive, affective, and conative responses to the map design. The evaluation involved semi-structured interviews with each target user. The following subsections provide a detailed description of the evaluation process, including participant selection, the design of the semi-structured interview, and how the interviews were conducted

3.5.1. Sampling respondents

Since the evaluation of map usability and user perception was conducted using qualitative research, purposive sampling was employed to select respondents for the user-testing phase. This sampling technique is widely recognized for its effectiveness in selecting relevant respondents who can provide rich, in-depth information to address specific research questions. In the process of purposive sampling, two key factors were considered when selecting respondents: context and participant criteria.

Given the *context* of this study, respondents needed to represent the target map users—those who are responsible for, or have an interest in, communicating landslide risk reduction to the general public. Respondents were drawn from two primary locations: local government agencies and Non-Governmental Organizations (NGOs) focused on disaster risk reduction. These two types of stakeholders were chosen because the majority of disaster communicators in Indonesia typically come from these sectors. The local government agencies were represented by the Regional Disaster Management Agency (BPBD) in Magelang and Kulonprogo Regency, while the NGO sector was represented by the Pujiono Center, headquartered in Sleman Regency. These stakeholders were selected because their work areas align with the scope of the VSGM mapping area, making them highly relevant to this study.

Table 3.2 The demographic information of the respondents

Respondent code	Institution	Gender	Age	Education	Job description
R1	BPBD	Female	26	Bachelor’s in Government Administration	Responsible for disaster prevention and preparedness agenda.
R2	BPBD	Female	56	Master’s in Education Management	Responsible for disaster prevention and preparedness agenda.
R3	BPBD	Male	34	Senior High School	Responsible for disaster information and communication management.
R4	BPBD	Male	32	Senior High School	Disaster response team.
R5	BPBD	Male	30	Bachelor’s in Socio-Political Science	Responsible for disaster prevention and preparedness agenda.
R6	NGO	Male	42	Master’s in Management	Disaster communicator and management team.
R7	NGO	Male	29	Senior High School	Disaster communicator and management team.
R8	NGO	Female	26	Bachelor’s in Agriculture	Disaster instructor in educational units.

The *criteria* for participant selection were based on both exclusion and inclusion factors. The exclusion criteria required respondents to meet the following conditions: 1) they must be responsible for communicating landslide risk reduction to the wider group of society, 2) they must have a minimum of one year of experience in their role, and 3) they should not have a formal educational background in geosciences, such as geomorphology, geology, geophysics or physical geography. For the inclusion factors, participant selection was not restricted by gender, age, level of education, or specific job positions within their organization.

In this qualitative research, theoretical sampling was employed to determine the sample size. Theoretical sampling is an iterative process of generating hypotheses through continuous data collection and analysis (Glaser & Strauss, 1967). This process continues until theoretical saturation is reached—when new data no longer produces novel theoretical insights (Charmaz, 2006). In this study, the researchers observed recurring patterns in the respondents' responses, including similar arguments, criteria, and themes, after interviewing eight respondents. Therefore, the sample size for evaluating the usability and users' perceptions of the map design was determined to be eight respondents. The identities and characteristics of these respondents are detailed in Table 3.2.

3.5.2. Semi-structured interview

Semi-structured interviews were employed in the user-testing methods for this research. This type of qualitative interview is recommended when addressing specific issues while maintaining a consistent answering style, allowing for cross-case comparability between respondents. In this study, semi-structured interviews were used to evaluate the usability of the map design and to understand users' perceptions of the map. A questionnaire was developed to guide the interviews which consists of four sections: 1) interview information, 2) participant demographics, 3) evaluation of map design usability, and 4) understanding users' perceptions of the map design.

Table 3.3 List of questions asked to each participant to evaluate the VSGM usability

Code	Questions	Map's substantive objectives
Q1	Can you identify the location of landslides?	Show the landslides' location and their characteristics.
Q2	Can you identify the difference type of landslides' activity?	
Q3	Can you explain the type of landslides commonly occur in this area?	
Q4	Can you explain the landslides causative factors in this area?	Explain landslides causative factors,
Q5	Can you point out areas with a high potential for landslides in the future? And explain why you choose that area?	Explain possible future scenarios of landslide hazards and impacts
Q6	Can you use this map to point out the high-risk area for landslides? And explain why you choose that area?	Design mitigation efforts to reduce the disaster risk.
Q7	Can you use this map to design mitigation efforts for reducing the landslide risk?	

Each participant was asked seven questions to assess the usability of the map design (Table 3.3). These questions were aligned with the four key roles that geomorphological maps play in landslide risk reduction, which the map makers aimed to communicate to the users. The usability evaluation was conducted using a coding system: a score of 1 was given if the participant answered correctly without assistance, a score of 2 if the participant answered correctly but required assistance, and a score of 3 if the participant was unable to answer correctly even with assistance from the interviewer.

For the next step, respondents were presented with six open-ended questions, each paired with a 5-point Likert scale, to assess how the VSGM influenced their perception of the use of geomorphological maps in landslide risk reduction (Table 3.4). The cognitive aspect was evaluated through two questions, which explored respondents' perceived map functionality and ease of use. The affective aspect was assessed through two questions aimed at uncovering the emotional responses respondents experienced after reading the VSGM. Lastly, the conative aspect was examined through two questions related to respondents' willingness to share and use the VSGM in the future.

Table 3.4 List of questions asked to respondents to evaluate user's perceptions of VSGM

Dimension	Sub-dimension	Questions (Item)	Likert scale
Cognitive	Perceived usefulness	How important is this VSGM for landslide risk reduction measures? Please explain your reasoning.	1= very unimportant 2= unimportant 3= neutral 4= important 5= very important
	Perceived easy to use	How easy is it for you to use this VSGM without the assistance of an expert like me? Please explain your reasoning.	1= very difficult 2= difficult 3= moderate 4= easy 5= very easy
Affective	Positive and negative emotion	Do you agree if this VSGM can enhance your capability as a disaster communicator? Please explain your reasons.	1= very disagree 2= disagree 3= neither agree or disagree 4= agree 5= very agree
		Do you agree if the wider group of society need to know and understand this VSGM? Please explain your reasons.	1= very disagree 2= disagree 3= neither agree or disagree 4= agree 5= very agree
Conative	Willingness to share	Will you eager to disseminate this VSGM to your colleagues? Please elaborate on your reasons and specify the recipients.	1= very unlikely 2= unlikely 3= neutral 4= likely 5= very likely
	Willingness to use	Will you utilize this VSGM in the future? Please explain your reasons and specify the purposes for which you will use it.	1= very unlikely 2= unlikely 3= neutral 4= likely 5= very likely

3.5.3. The procedure of interview

The procedure of interview in user-testing based evaluation is illustrated in the Figure 3.8. The first step involved identifying respondents who met the criteria for map users (as detailed in Section 3.3.1) and scheduling appointments for interviews. On the day of the interview, the researcher provided a brief overview of the study's objectives and explained the interview process in detail. Respondents were then asked to sign a consent form, confirming their voluntary participation in the study.

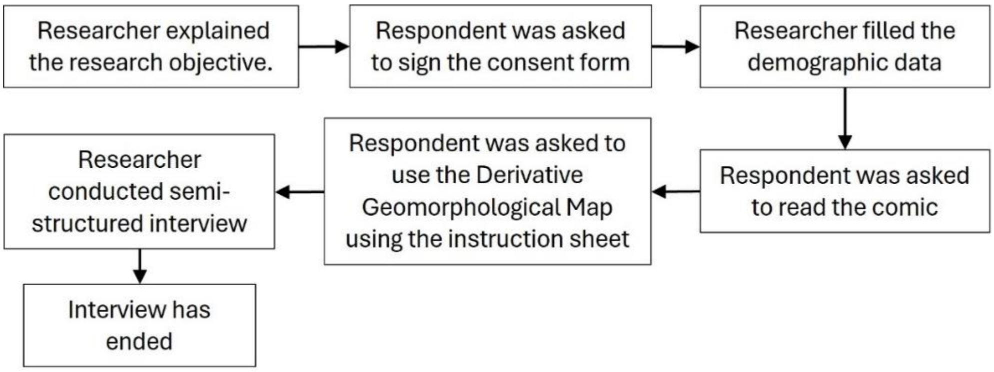


Figure 3.8 The flow of interview with respondent.

The interview sessions were conducted indoors at the BPBD Magelang Office and the NGO Secretariat Office in Sleman, Indonesia. The researcher served as the interviewer, while respondents participated alongside an assistant researcher responsible for documenting the process. The tools utilized during the interviews included a prototype of the VSGM presented as printed sheets for respondents to use, a questionnaire to guide the in-depth discussions, a voice recorder to capture audio for transcription purposes, and a digital camera for visual documentation.

After interviewer asked about the demographic data, respondents were asked to read a comic. Following this, they were instructed to read the map using the guidelines provided on the map reading instruction sheet. Once respondents had interacted with the VSGM prototypes, the interviewer conducted a semi-structured interview (explained in more detail in Section 3.4) to assess how easy the map was to use and to gather respondents' perceptions after using it. The entire interview was recorded using a voice recorder and supplemented with photographs for documentation purposes. Each interview session lasted approximately 30 to 45 minutes. As a token of appreciation, respondents received either a box of Taiwanese tea or Rp. 100,000 at the end of the interview. The documentation during the interview is presented on the Figure 3.9.

Figure 3.9 Documentation of the interview process with each respondent

3.6. Conducting SWOT analysis

A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was employed to formulate recommendation for the future development of VSGM as landslide risk communication tool. In the initial stage, the internal strengths and weaknesses of the VSGM were identified based on the empirical results of user testing-based evaluation. Simultaneously, the external opportunities including the potential for wider adoption in Indonesia and other high-risk regions was explored. The possible barriers to the wider production of VSGM, such as resource constraints or technological limitations were also examined. The insights gained from this analysis provide a comprehensive foundation for refining the VSGM and maximizing its impact on landslide risk communication in the future.

3.7. Data analysis

1) **Sub-objective 1:** The creation of the VSGM designed using co-production approach. The VSGM design process, developed through co-production, is analysed using narrative analysis. The narrative begins with the creation of the first draft of the VSGM by the main team, followed by a detailed account of the feedback provided by each member of the supporting team. It then describes the adjustments made by the main team in response to this input, leading to the final version of the map design. The narrative concludes by highlighting how the co-production technique influenced the final outcomes and the overall design quality of the VSGM.
2) **Sub-objective 2:** The usability evaluation representing the cartographic quality of the VSGM design. In this research, the usability evaluation focused on how respondents used the VSGM to answer the interview questions. The more questions respondents answered correctly without interviewer assistance, the higher the usability level of the map design. A high usability level indicates that the VSGM design is easily understood, allowing users to grasp the map's intended message. Usability is a key factor in assessing the cartographic quality of a map, as a well-designed map must effectively and clearly communicate its message to users.
3) **Sub-objective 3:** The effect of VSGM design in shaping users' perception towards geomorphological map. A thematic analysis was employed to examine how the VSGM influences users' perceptions of the role of geomorphological maps in landslide risk reduction efforts. The process involved identifying codes and determining themes from the interview transcripts to build a framework that describes users' perceptions after interacting with the map, considering

cognitive, affective, and conative aspects. In the cognitive aspect, the analysis explores how well users understand the function of geomorphological maps in landslide risk reduction and their perceived ease of use. The affective aspect focuses on the emotional outcomes experienced by users after engaging with the VSGM. Lastly, the conative aspect assesses users' willingness to use and disseminate information about the VSGM, providing insights into how the map influences their intentions and actions.

4) **Sub-objective 4:** The recommendation for future development of VSGM as effective an effective tool for landslide risk communication. Recommendations for the optimal use of visual storytelling approaches in geomorphological map design were developed through a comprehensive SWOT analysis. The formulation of these recommendations was based on three primary considerations. First, the analysis focused on leveraging the strengths of the VSGM to capitalize on existing opportunities. Second, it examined approaches to mitigate the identified weaknesses, thereby minimizing risks that could potentially hinder the map's effectiveness and broader adoption. Third, the analysis emphasized employing the strengths and opportunities to mitigate the impact of potential threats, including limitations in resources and resistance to adopting new methodologies. These recommendations are intended to enhance the usability, user's perception, and long-term effectiveness of visual storytelling in geomorphological mapping, ultimately improving its value as a tool for landslide risk communication and disaster risk reduction.

3.8. Reliability and validity of data

In this qualitative research, the four criteria of trustworthiness proposed by (Guba EG & Lincoln YS, 1994) were used to ensure the validity and reliability of the data. To meet the criterion of credibility (internal validity), respondents in the user-testing activity were intentionally not restricted by gender, age, or educational background. This approach was taken to capture a wider range of perspectives and more diverse insights into the social reality being studied—in this case, the perceived quality of the VSGM design. To satisfy the criterion of transferability (external validity), the research context has been described in as much detail as possible, including the purpose of the interviews, participant characteristics, and the interview questionnaire used as the measuring instrument.

The dependability criterion, which ensures the reliability of the data, was addressed by thoroughly documenting the entire research process from start to finish. Throughout the co-production of the map and the user-testing activities, researchers maintained detailed records, including photos, voice recordings, transcripts, and participant consent forms. All documentation was carefully organized to allow for future replication and auditing of the research process. To meet the confirmability criterion, member checking and triangulation techniques were used to minimize researcher bias. Member checking was conducted during the validation process of the VSGM design draft with the supporting team. Additionally, the use of a Likert scale in open-ended questions served as a form of triangulation, helping to validate respondents' responses and perceptions.

3.9. Ethic clearance

The entire data collection process involving human respondents in this study adhered to established ethical standards, ensuring the protection of respondents' rights and well-being. Ethical approval for the research was obtained from Universitas Gadjah Mada, as evidenced by the ethics clearance document, which is referenced under the number No: KE/UGM/073/EC/2023. This document confirms that the study complied with all necessary ethical guidelines, including informed consent, confidentiality, and the respectful treatment of respondents throughout the research process. The ethics clearance document, which is provided in the Indonesian language, can be found in Appendix 13. This ethical adherence is crucial for maintaining the integrity of the research and ensuring that all human-related data collection was conducted responsibly and in accordance with institutional and international research ethics principles.

Chapter 4 - Results: Co-Production of The VSGM Design

4.1. The first draft of VSGM result

The process of designing the first draft of VSGM prototype consisting of a Derivative Geomorphological Map, comic and instruction sheet is explained in detail in the following sub-sections.

4.1.1. Derivative Geomorphological Map (DGM)

a) Audience/ User

The DGM is specifically designed for an audience that meets three key criteria. Firstly, it targets adults aged 18 years and older. Secondly, it is intended for experienced landslide communicators with at least one year of experience in disseminating critical information about landslide risk reduction to the broader public. These individuals may be professionals or enthusiasts dedicated to raising awareness of landslide risks. Lastly, the DGM is tailored for non-experts in geoscience fields such as geomorphology, geology, physical geography, or geophysics, ensuring accessibility for those without specialized technical knowledge.

b) Objectives

The map's objectives encompass the core message the map creator intends to communicate with the user. The objective serves as a framework for determining which information should be included and emphasized. In map design, three types of objectives are typically defined: substantive objectives, which focus on the key information to be conveyed; action objectives, which outline the tasks users are expected to perform using the map; and affective objectives, which aim to evoke specific subjective feelings of the user. In this study, the three objectives for the DGM are detailed in Table 4.1.

Table 4.1 Objectives of the Derivative Geomorphological Map in the VSGM

Type of objectives	The context of Derivative Geomorphological Map.
Substantive objectives	Improving spatial awareness of hazards and risk at the local scale and facilitating site-specific mitigation actions, by showing the large-scale geomorphological map's roles in DRR: • show the landslides' location and their characteristics. • understand landslide causative factors, • understand the possible future scenarios of landslide hazards and their impacts, and • design mitigation efforts for disaster risk reduction
Action objectives	Seven tasks that must be done by users to achieve the substantive purposes are: o *Task 1*: identifying the location of landslides. o *Task 2*: identifying the difference type of landslides' activity o *Task 3*: explaining the type of landslides commonly occur in the mapping area o *Task 4*: explaining the landslides causative factors o *Task 5*: pointing out and explaining areas with a high potential for landslides in the future. o *Task 6*: using DGM to point out and explain the high-risk area for landslides. o *Task 7*: using DGM to design mitigation efforts for reducing the landslide risk.
Affective objectives	Promoting the use of large-scale geomorphological maps in DRR among non-experts.

c) Map presentation

The development of the Derivative Geomorphological Map (DGM) involved several critical considerations to ensure its effectiveness in communicating landslide risks. There are at least five aspects that need to be addressed to define the DGM presentation. These thoughtful design choices ensure that the DGM serves as both an informational tool and an interactive learning resource, effectively supporting landslide risk communication and decision-making. Those aspects are explained as follows:

- **Data Source and Map Scale.** The primary resource for the DGM is a 1:2,500 basic geomorphological map developed by Pratiwi et al. To maintain consistency and fidelity with the source data, the

DGM was produced at the same scale of 1:2,500. This ensures that the spatial accuracy and detail required for effective analysis and interpretation are preserved.

- **Interface Design**. The DGM is presented as a static printed map on A0-sized paper, which allows for detailed visualization and broad accessibility. This format eliminates the need for specialized hardware or software, making the map usable in a variety of settings without technological barriers.
- **Map Layout and Information Types**. The DGM's layout and information organization are thoughtfully designed by emphasizing the aspect of **attention** and **dosing** (see Table 2.1 for the definition) to help users do the tasks and understand the map's purposes. The A0-sized map is divided into nine frames (A to I), as shown in Figure 4.1, while Table 4.2. summarizes the information in each frame and explains its significance to the map.

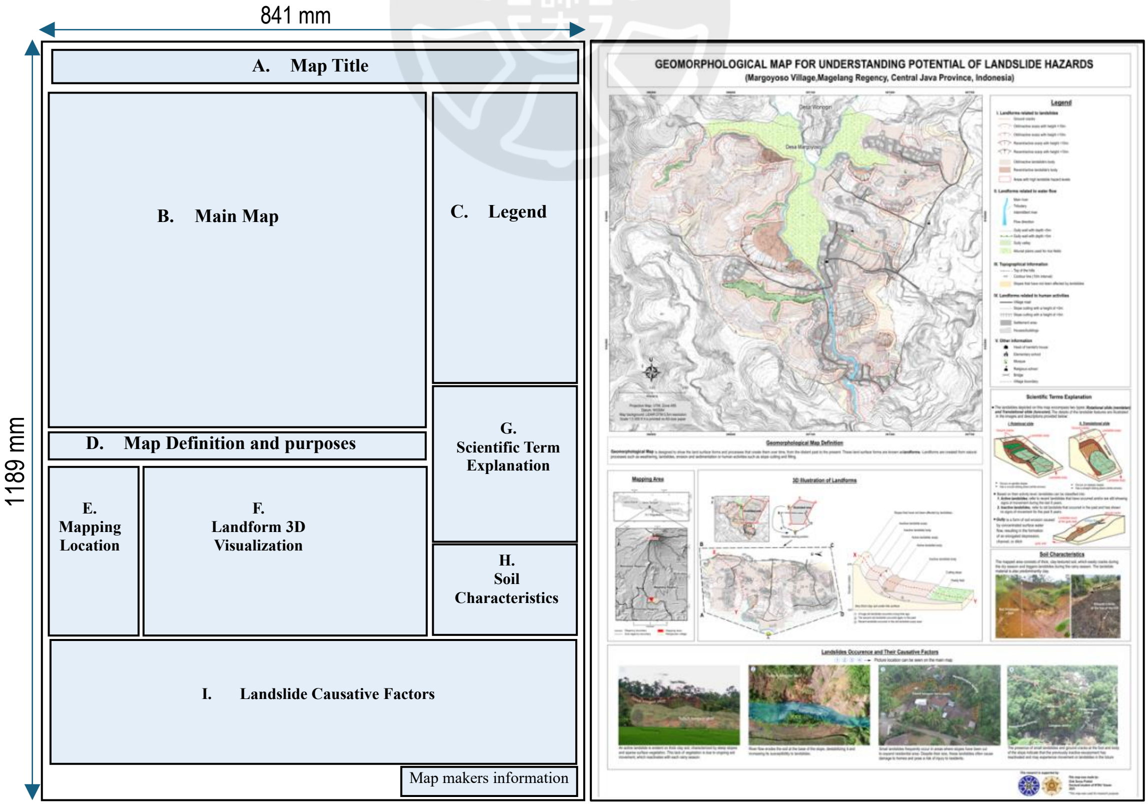


Figure 4.1 The first draft of the Derivative Geomorphological Map. (a) Layout and (b) map preview.

Table 4.2 Type of information within each frame on the Derivative Geomorphological Map

Map frame	Type of information	Objective of the information
A. Map Title	Geomorphological map's title	Setting the context and drawing attention to the key themes of the map.
B. Main Map, and C. Legend	Landslide features	Displaying the exact location and extent of landslide features, including cracks, scarps, and bodies. *(for **Task 1**)*
	Landslide activity level	Showing landslide activity information (inactive and active) to differentiate the level of hazard. *(for **Task 2**)*
	Landslide hazardous area	Explicitly showing areas that have a higher potential for landslide hazards. *(for **Task 5**)*
	River network Gully channel Slope cutting	Showing the geographical context of factors contributing to the development of landslide hazard areas. *(for **Task 5**)*
	House/ building Road network Settlement platform Alluvial plain for paddy field	Showing elements at risk potentially impacted by landslides and highlighting high-risk areas prioritized for disaster risk reduction (DRR) agenda. *(for **Task 6 and Task 7**)*
	3D Visualization-based LiDAR DTM Contour line	Help users in understanding elevation and emphasize terrain features, enhancing the clarity of landforms.
	Landmarks	Help users familiarize themselves with the mapping location
D. Map Definition and Purposes	Description of geomorphological map definition and purposes	Help users familiarize themselves with the map theme and goals
E. Mapping Location	Inset map	Help users familiarize themselves with the administrative location of the mapping area
F. Landform 3D Visualization	3D visualization of the geomorphological map 3D cross section of landform	Providing vivid visualization on the landform and landslides shapes

Continued table

Frame	Type of information	Objective of the information
G. Scientific Term Explanation	Sketches of landslide types and gully erosion	Providing knowledge on landslide types and gully erosion *(for **Task 3**)*
H. Soil Characteristics	Photos of soil condition	Showing the real picture of the material type in the study area
I. Landslide Causative Factors	Photos of landslides causative factors	Showing the real picture of the landslide causative factors in the study area. *(for **Task 4**)*

Most of the map is allocated to the main map (frame B) and the legend (frame C). These frames provide information derived from the process of selecting, adding, or generalizing data from the basic geomorphological map to align with the purposes of the DGM. There are at least thirteen types of information that are important to display to demonstrate the role of geomorphological maps in understanding landslide hazards and risks.

As this map seeks to emphasize the role of geomorphological maps in enhancing landslide risk reduction, the primary information to highlight in the main map is the spatial distribution of landforms influenced by gravitational forces. Large-scale landslide mapping is crucial for providing users with clear visualizations of features associated with landslide occurrences, such as cracks, scarps, and bodies, as well as the actual and potential size of landslides. Representing landslides as areas with their real dimensions is highly beneficial for helping map users grasp the magnitude of a landslide's destructive power.

The second key information to highlight is the level of landslide activity, which helps users differentiate between vulnerability and hazard. While most areas are susceptible to landslides, not all have high hazard potential. Based on basic geomorphological map, landslide activity levels are categorized into four types: relict, active, dormant, and suspended. A qualitative study by Lo et al., (2017) suggests that relict landslides have a lower reactivation potential and thus a lower hazard level compared to the other three. To simplify the data, the DGM design generalizes landslide activity into two classes: recent or active landslides (combining active, dormant, and suspended) and old or inactive landslides (relict).

The third essential information to display is a symbol referring to areas with higher landslide hazard levels and the factors contributing to their increased hazard. In this study area, zones near recent or active landslides are particularly hazardous. According to Pratiwi et al., the primary factors triggering landslides in this area include surface water erosion and slope-cutting activities. Therefore, landforms associated with fluvial processes and human activity such as slope cutting should be added to identify landslide hazardous area apart from recent landslides itself.

Anthropogenic landforms, such as houses, buildings, roads, and agricultural assets, that could be affected by landslides should be included on the map. These features serve as critical exposure elements, helping users better understand the concept of risk. By presenting this information, users can visualize the potential impacts of landslides and compare risk levels across regions. Highlighting exposure elements offers a more tangible depiction of risk, allowing users to grasp the real-world consequences, rather than relying solely on abstract mathematical risk assessments such as degree of risk information.

In this research, a 3D visualization-based LiDAR DTM and contour lines were utilized as the primary background for the main map. These elements were chosen to emphasize terrain features, enhancing the clarity and visibility of landforms. Aerial photographs were deliberately excluded as a background layer due to the dense land cover and the relatively small elevation variations in the study area, which would have hindered the effective visualization of landforms.

Finally, including landmarks on the map is equally important, as they play a vital role in helping users familiarize themselves with the mapping location. Landmarks serve as reference points that make the map more relatable and user-friendly. These can include public facilities such as schools, hospitals, or community centres, as well as road names and place names. By incorporating such recognizable features, the map not only enhances spatial awareness but also provides a context that aids users in interpreting other information, such as hazard zones or areas at risk of landslides.

- **Visualization Technique**. A diverse range of visualization techniques is employed to convey the data effectively. For the main map, a combination of pictorial and geometric symbols is used to represent features. Instead, sketches and oblique aerial photographs are incorporated into additional frames. These elements are particularly useful for non-expert users, as they provide a clearer representation of the environmental reality and assist in visualizing the landscape. The derivative geomorphological map was designed using ArcGIS Desktop software, with additional graphic enhancements made using Corel Draw.
- **Cognitive Engagement and Task-Based Interaction**. The DGM is designed not only to deliver information but also to engage users in higher levels of cognitive learning. It encourages users to apply the map to solve real-world problems, fostering two-way interaction between the map and the user. The map explicitly presents information needed to answer tasks 1 to 5, providing foundational knowledge. For tasks 6 and 7, users are challenged to synthesize and apply their understanding from the earlier tasks. Task 6 involves identifying high-risk areas by analyzing the spatial relationships between landslide hazard zones and at-risk elements such as buildings, roads, and houses. Task 7 requires users to

prioritize locations for disaster mitigation. By correctly interpreting the map, users should identify high-risk areas as priority zones for disaster risk reduction.

d) Condition of use

The DGM is designed for versatile use in both indoor and outdoor settings, accommodating various practical applications. In indoor environments, such as classrooms or laboratories, the map can be utilized throughout the day, benefiting from controlled lighting and temperature conditions. Conversely, in outdoor settings, its use is limited to daytime hours when adequate natural light is available, ensuring the map remains legible. Furthermore, the DGM is designed for flexible engagement, supporting both individual use and collaborative discussions in group settings, enhancing its utility across diverse scenarios.

To use the DGM effectively, users are first encouraged to read the accompanying comic and then it is followed by reading the DGM using the instruction sheet (Figure 4.2). The comic introduces key concepts, including what a geomorphological map is, the types of problems it can address, and how it provides solutions. Once familiar with these ideas, users can proceed to explore the map itself with the assistance of the instruction sheet. This sheet provides step-by-step guidance on how to read and extract information from the DGM, helping users easily grasp the map's implied messages.

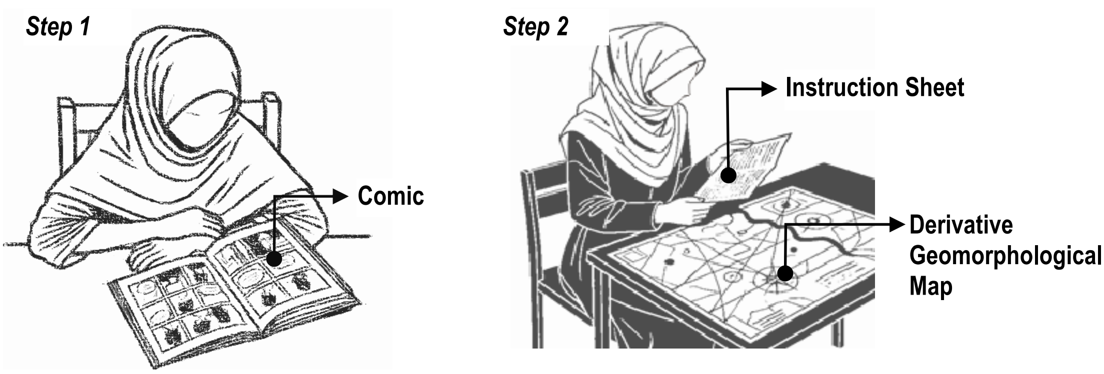


Figure 4.2 Process of using the VSGM

4.1.2. Comic

Comic is the first visual story based supporting media for DGM. The following section provides a detailed account of the process involved in crafting the comic's storyline which, follows the three-act narrative structure (Figure 4.3) and its graphic design. Both storyline and graphic design of the comic were carefully created and emphasized the aspect of **continuity, voice, metaphor** and **mood** (see Table 2.1 for the definition).

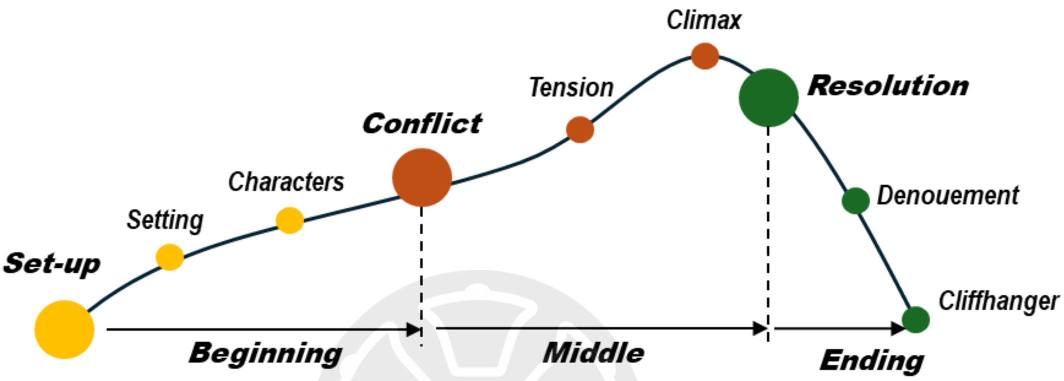


Figure 4.3 The Three-Act Narrative Structure as a Framework for Comic Storylines

a) **Storyline**

- **Set-up (Beginning).** The story begins by establishing its ***setting*** and ***characters***, creating a relatable context for the narrative. The story takes place in the BPBD office in Magelang District, which serves as the geomorphological mapping area featured on the VSGM. The central character is Mr. Jalu, a new employee at the Regional Agency for Disaster Management (BPBD) in Magelang. He represents the target audience for the VSGM—a disaster communicator tasked with disseminating risk information yet lacking a geoscience background. Mr. Jalu is guided by Ms. Rina, a senior employee with extensive experience in disaster management, who provides mentorship and technical insights. The third character, Mr. Udin, is the head of a nearby village seeking assistance to implement landslide mitigation measures in his community. The last character is a head of BPBD office who act as a supporting actor.

- **Conflict (Middle part).** The story's conflict centres on the common challenges faced by disaster communicators in Indonesia, particularly the difficulty of offering effective risk reduction recommendations due to limited data and insufficient understanding of landslide hazards and risks. In the narrative, the ***tension*** began when Mr. Udin comes to Mr. Jalu and requests for guidance on mitigating landslide risks in his village and identifying priority areas for immediate action. The ***climax*** of this story is when Mr. Jalu feels uncertain and lacks the confidence to provide a definitive response since he is a new employee unfamiliar with the village's condition.
- **Resolution (Ending).** The resolution of the story brings the map user acknowledging the dual objectives of the DGM. The first is the substantive objective, which emphasizes the vital role of geomorphological maps in improving landslide risk reduction efforts. In the narrative, the substantive objectives are a foundation to create the ***denouement*** of the conflict where Ms. Tiwi introduces Mr. Jalu to the geomorphological map, demonstrating how it can help overcome his challenges and provide practical solutions. The second is the affective objective, which emphasizes the feeling of the map user through the geomorphological map. In this story, the affective objectives were used to create the ***cliffhanger***. At the end of the story Mr. Jalu appreciates the map's significant benefits in enhancing landslide mitigation strategies. He also comes to understand and value the geomorphological map as an indispensable tool for disaster communicators like himself.

b) Graphic design

The graphic design incorporates metaphorical and mood elements to effectively convey key messages in a visually engaging, easily understandable, and relevant manner. Created digitally on B5 paper (250 mm x 176 mm), the four-page comic features characters engaged in dialogue. It uses a minimalist black-and-white colour scheme to emphasize simplicity and focus the readers' attention on the dialogue. An example of the comic's first page is shown in Figure 4.4.

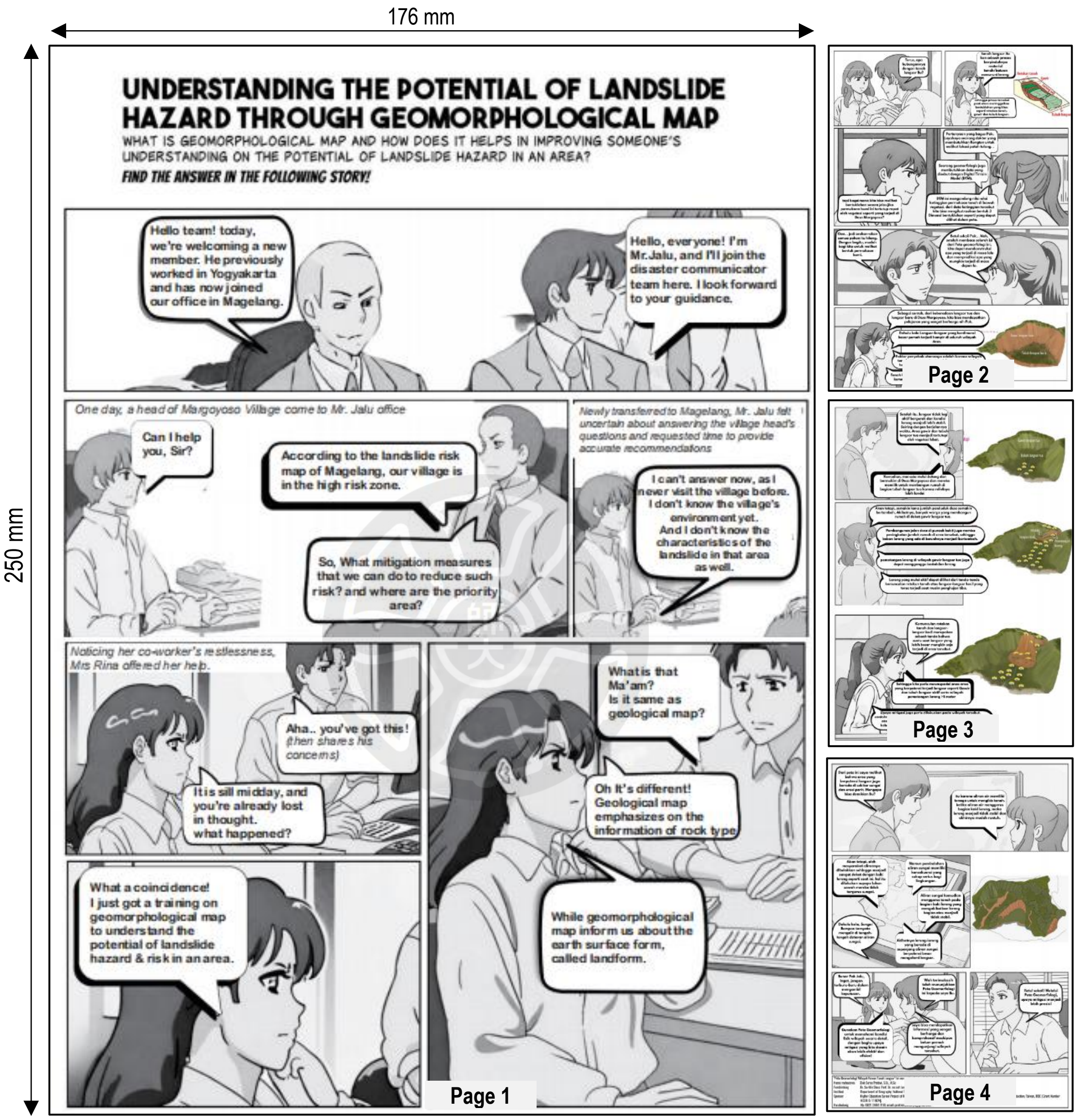


Figure 4.4 Graphic illustration of the comic

4.1.3. Instruction sheet

An instruction sheet is the second visual story-based supporting media for DGM. The following section provides a detailed account of the creative process involved in crafting the instruction sheet's content and graphic design, emphasizing the aspect of **continuity** and **dosing** (see Table 2.1 for the definition).

a) **Instruction sheet's content**

The content of the instruction sheet includes key elements such as 1) the definition of a geomorphological map, 2) the process of creating the map, 3) the intended target users, and 4) suggestions on how to effectively read and understand the map. The explanation of what a geomorphological map is, how it is created, and who it is designed for is presented with careful attention to visual storytelling tropes, particularly dosing and continuity. The dosing trope is applied by providing a concise summary, ensuring that complex information is broken down into manageable, easily digestible portions. Additionally, the continuity trope is utilized to guide users with clear, step-by-step instructions, encouraging them to follow a logical progression from start to finish.

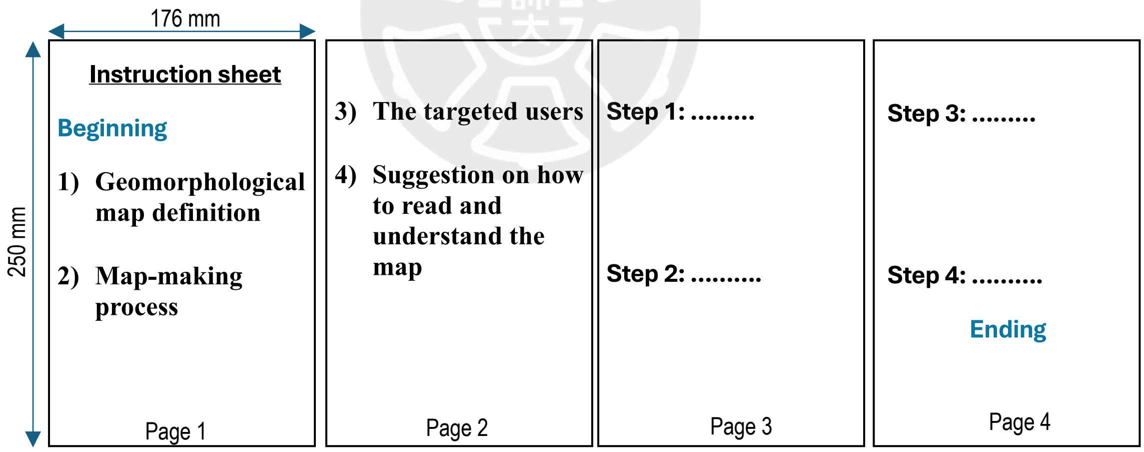


Figure 4.5 Layout illustration of the instruction sheet

b) **Graphic design**

The instruction sheet is designed as a printed booklet consisting of four pages, each created on B5-sized paper. These pages are structured to present the four main components essential for map users to follow and understand the map's message effectively. The content is carefully organized to guide users step-by-step, ensuring clarity and ease of comprehension. A graphic design illustration of the instruction sheet is provided in Figure 4.5, showcasing its layout and content elements.

4.2. Co-production process

Once the first draft of the VSGM was developed by the main team, an initial meeting with the supporting team was organized to assess whether the map's objectives aligned with user needs and to identify any necessary modifications (Figure 4.6). In response to the first question, all seven members of the supporting team, which included professionals and target users, unanimously agreed that the VSGM's objectives effectively addressed the needs of disaster communicators in Indonesia (see Appendix 1). Expert 2, a disaster management professional, emphasized that disaster communicators have long required media that enhance their understanding of hazards and risks within a geographical context.

"*Most disaster communicators in Indonesia rely on theoretical books or brief expert lectures to grasp landslide hazards, risks, and mitigation strategies. However, the information they receive is generally framed in a global context, leaving a gap in resources that could aid their understanding in a more localized and practical manner for their area of work.*" Said Expert 2.

One of the target users, also shared that the information VSGM aims to convey has been a longstanding need.

"*In our office, the only map-based tool for landslide disaster communication is a district-level risk map. The maps provide very minimal information; they only indicate high- and low-risk areas, mainly for planning evacuation routes. When we're asked to recommend specific locations for mitigation efforts, like installing Early Warning Systems (EWS) or slope reinforcement, it becomes challenging because we don't really know the landslide distribution very well, and we usually have to seek expert advice for that*," said Map User 1.

After confirming that the VSGM objectives align with the needs of map users, the co-production process proceeded through several stages: gathering feedback from the supporting team, making design adjustments, and finalizing the design. The outcomes of this process are detailed in the following sub-chapter.

Figure 4.6 The documentation of the meetings with the supporting team. a) Map user. b) Disaster management expert. c) Design illustration expert. d) Geography education expert. e) Geomorphological mapping expert. f) Learning media expert.

4.2.1. Feedback data collection

Every member of the supporting team was asked to write their comments, critics or impressions after using VSGM. During the feedback gathering process, 21 responses suggesting the need for improvements in the VSGM design were successfully collected. All the feedback was analysed and synthesized to identify areas for improvement in the VSGM. Overall, the feedback highlights four sectors needing enhancement: the storyline, comic illustration design, map instruction sheet design, and main map presentation design (Table 4.3).

Table 4.3 Categorisation of area for improvement and their aspects based on the supporting members' feedback.

Area for improvement	Aspects	Salient points of the feedback
Comic storyline	Character selection	To strengthen the emotional connection between the map and its users, we can introduce characters in the comic who share the same profession as the map users. This will help create a more intimate bond. Because our goal is to make it easier for map users to understand the benefits of the maps in supporting their work, thereby increasing the likelihood of future use. [DM]
	Conflict construction	The issues presented in the story are more effective when they resonate with the common challenges frequently encountered by map users. [DM]
	Resolution development	I believe it is unnecessary to dive into the technical details of map creation. Instead, it's more beneficial to clearly explain why users should use the map and what valuable information they can gain from it. [DM]
Comic illustration design	Visual composition over the text	In comics, prioritizing the visual composition over text is essential. [GI]
		The comic dialogue remains excessively dense and makes me quickly lose interest. [MU1]
		Overall, the comic visualization and illustrations are less attractive because the dialogue is too dense. [MU2]
	Visual quality	The illustrations used in this comic are too stiff, lack colour, and limited pictures. [GI]
	Visual function	The images and illustrations presented should be fitting and capable of complementing the accompanying dialogue. [GI]
		Introducing casual dialogue or humour into the story is necessary at times to prevent the storyline from becoming dull. [GI]
Instruction sheets design	Visual composition over the text	The explanation on the map instruction sheet is too dense. It is better to reduce the definition and map making process section. [LM]
		The instruction sheets are overly verbose, discouraging me from reading them due to the excessive text. [MU2]
	Elements that can link to the map	It is better to put elements on the map instruction sheet that can link it to the map. For instance, we can consider how companies design instruction sheets

		for using electronics by incorporating photographs that closely resemble the actual tools and including clues that guide users to specific parts within the tool. They can keep the instructions concise yet informative. [LM]
	Reading order	Giving the sequence for reading the map will enhance users' ability to grasp the intended message more effectively. [LM]
Derivative Geomorphological Map presentation	Data layers	The main information on the map should focus on landslide activity information and element at risk as this data are very important for assessing the level of landslide hazard and risk. I believe those data are very important for the user to set priorities for disaster management. [GM]
	Symbology	I feel that some of the symbols on the map have almost the same colour, so it is difficult for me to differentiate them. [MU2]
	Composition	Explicitly stating the map's purpose on the main map will be very helpful. Apart from helping users identify the information they can extract from the map; this also allows researchers to more easily assess the usability level of the map. [GE] The inclusion of photos on the map really helped me understand the actual conditions of the mapped area. [MU2] The 3D landform illustration space can be further utilized. For instance, we can incorporate 3D illustrations of landslide-prone areas from Google Earth or UAV-based aerial photos. By doing this, users will understand the significance of mapping landslide areas using LiDAR, as landslide-prone areas are not as clearly visible when relying solely on Google Earth satellite imagery or UAV aerial photos. [GM]
	Lettering	This detail 3D visualization really helps me to imagine the shape of the topography and landslides. [MU2] Simplifying the narrative text that describes the images/photos on the map is very important. So, we need to be careful in choosing images/photos that can communicate the intended message effectively. [GM] Minimizing the utilization of academic terminology in maps is advisable. If the use of such terms is necessary, it is crucial to offer explanations in a

	simple and understandable manner for the general audience. [DM]

The feedback was gathered from geomorphological mapping expert [GM], disaster management expert [DM], geography education expert [GE], learning media expert [LM], graphic illustration expert [GI], map user 1 [MU1], and map user 2 [MU2].

4.2.2. Map modification result

Key elements of the comic's storyline that were highlighted by the supporting team for improvement include character selection, conflict construction, and resolution development. Making the map user the main character in the story is crucial for establishing an emotional connection, making the narrative more engaging for the audience. Consequently, the main character is portrayed as a disaster communicator working at the BPBD Magelang office, aligning with the role and location of the target map users. Additionally, incorporating common challenges faced by map users in their workplace as central conflicts in the story enhances its relatability and mirrors the user experience, thereby fostering a stronger connection with the narrative. Finally, the resolution should clearly articulate the reasons for using the geomorphological map and the valuable insights it offers, thereby emphasizing the practical benefits of the story for the readers.

The supporting team identified several key elements of the comic illustration design that required improvement, focusing on enhancing the overall effectiveness and appeal of the visual content. First, the visual composition in relation to the text was emphasized, highlighting the need for a more harmonious balance between imagery and narrative. This balance is essential to ensure that the illustrations not only complement but also enhance the storytelling, making it more engaging and easier to follow.

Additionally, the visual quality was pointed out as a crucial factor, with recommendations to improve the clarity, colour schemes, and overall aesthetic of the illustrations to make them more visually appealing and professional. Finally, the team underscored the importance of visual functionality, emphasizing that the illustrations should not only be attractive but also serve a practical purpose. For example, they should effectively guide the reader's understanding scientific terminology about geomorphology, landslide and disaster risk. Addressing these elements is vital to creating a more impactful and user-friendly comic illustration design. The revision of comic design was then conducted based on the second team feedback and illustrated in Figure 4.7.

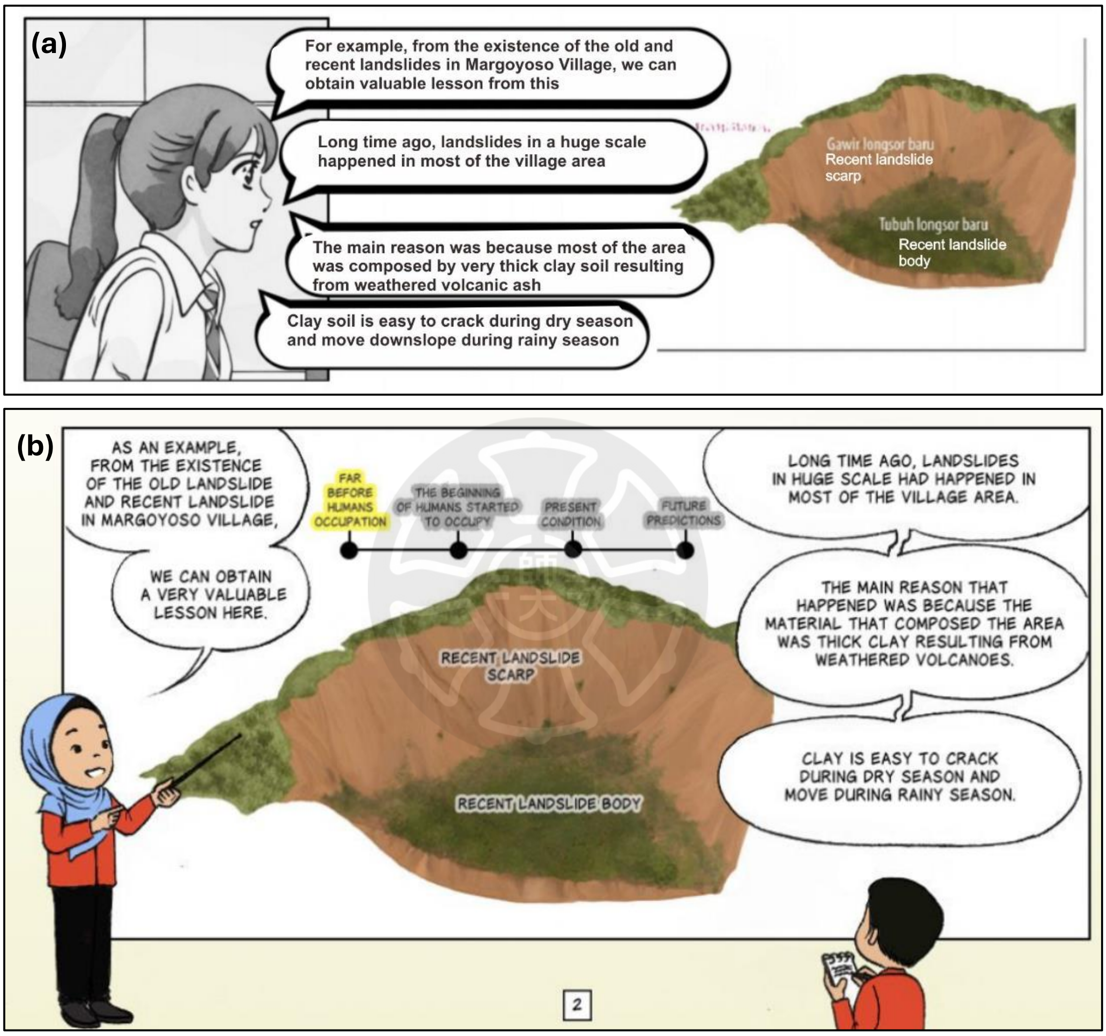


Figure 4.7 The comparison of comic visualization between before and after adjustment process. a) The first draft. b) The revised version. (See supplementary data 3 and 6 for the actual size)

The supporting team identified several key elements of the map instruction sheet design that needed improvement to enhance its clarity and effectiveness. First, they emphasized the importance of visual composition in relation to the text, noting that the layout should be carefully balanced to ensure that visual elements support and enhance the written instructions rather than overshadowing them. According to their feedback, the first draft of the instruction sheet contained overly dense text, which discouraged users from reading all the instructions. To address this, it would be beneficial to reduce the amount of text and emphasize image-based instructions. Achieving a balance between text and visuals is essential to maintain user focus and make the information more accessible.

Second, the team pointed out the need for elements that can directly link to the map itself. These could include icons, symbols, or references within the instruction sheet that correspond to specific features on the map, helping users to easily connect the instructions with the actual map content. Finally, the reading order was highlighted as a critical aspect, with recommendations to structure the information in a logical, intuitive sequence that guides the user smoothly through the instructions. This ensures that the instruction sheet is easy to follow and effectively supports the user in understanding and utilizing the map. In response to the feedback gathered from the supporting team, the first draft of the instruction sheet was revised, reducing its length from four pages to two pages. A comparison between the revised version of instruction sheet and the original (first) draft is shown in Figure 4.8.

The final area of improvements suggested by the supporting team revolves around enhancing the map presentation design, focusing on data layers, symbology, composition, and lettering. Examples of elements that required significant modification included the map composition section. To better illustrate landforms in three dimensions, the use of space within the frame needed to be optimized. This could involve adding a comparison between the geomorphology map's visualization of the earth's surface and real-world conditions depicted by Google satellite imagery. Additionally, explicitly presenting the four map objectives in a separate frame was suggested as a way to help users more easily grasp the key messages of the VSGM.

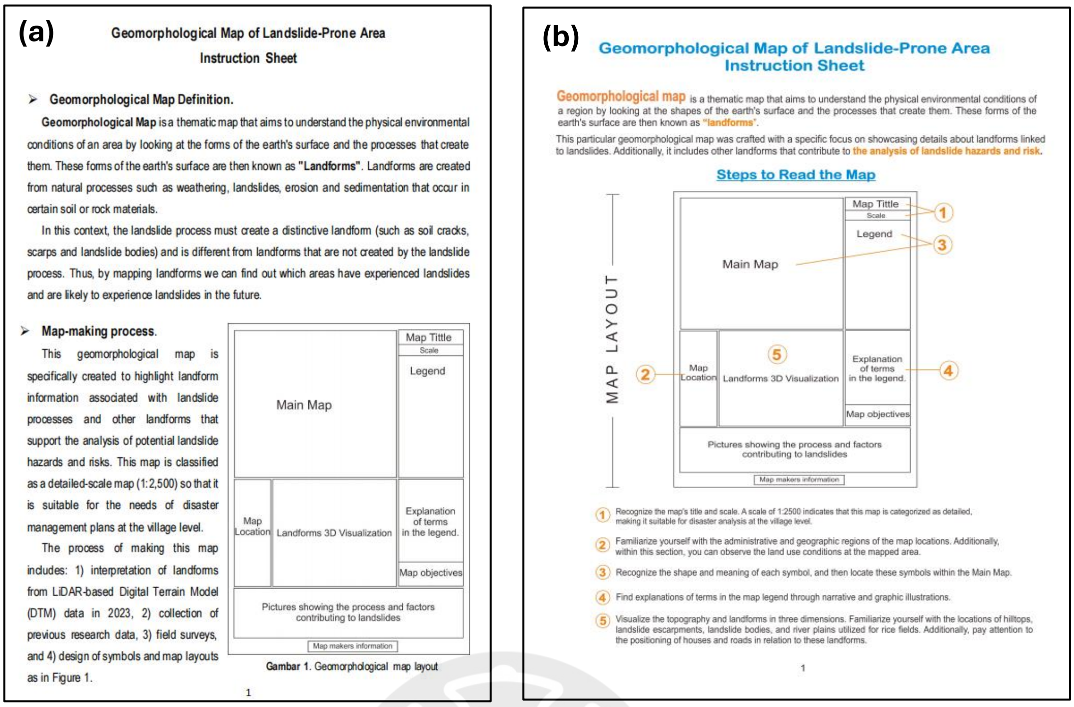


Figure 4.8 The comparison of the instruction map before and after the adjustment process. a) The first draft. b) The revised version. (See supplementary data 4 and 7 for the actual size)

In terms of symbology, users have expressed a preference for more distinct colours to better differentiate landslide characteristics on the map, making these features easier to identify. In addition, map composition introducing a dedicated frame that clearly outlines the map's objectives is essential, as it helps guide users to quickly understand the map's purpose. For dimensionality, incorporating 3D visualization that accurately represents topographic conditions and terrain surfaces is highly recommended, as it deepens users' geographical understanding of the area depicted. Finally, it is advisable to minimize the use of excessive text on the main map. Instead, opting for representative images or photographs that effectively communicate the intended message is strongly encouraged. A comparison between the modified derivative geomorphological map (second) draft and the original (first) draft is shown in Figure 4.9.

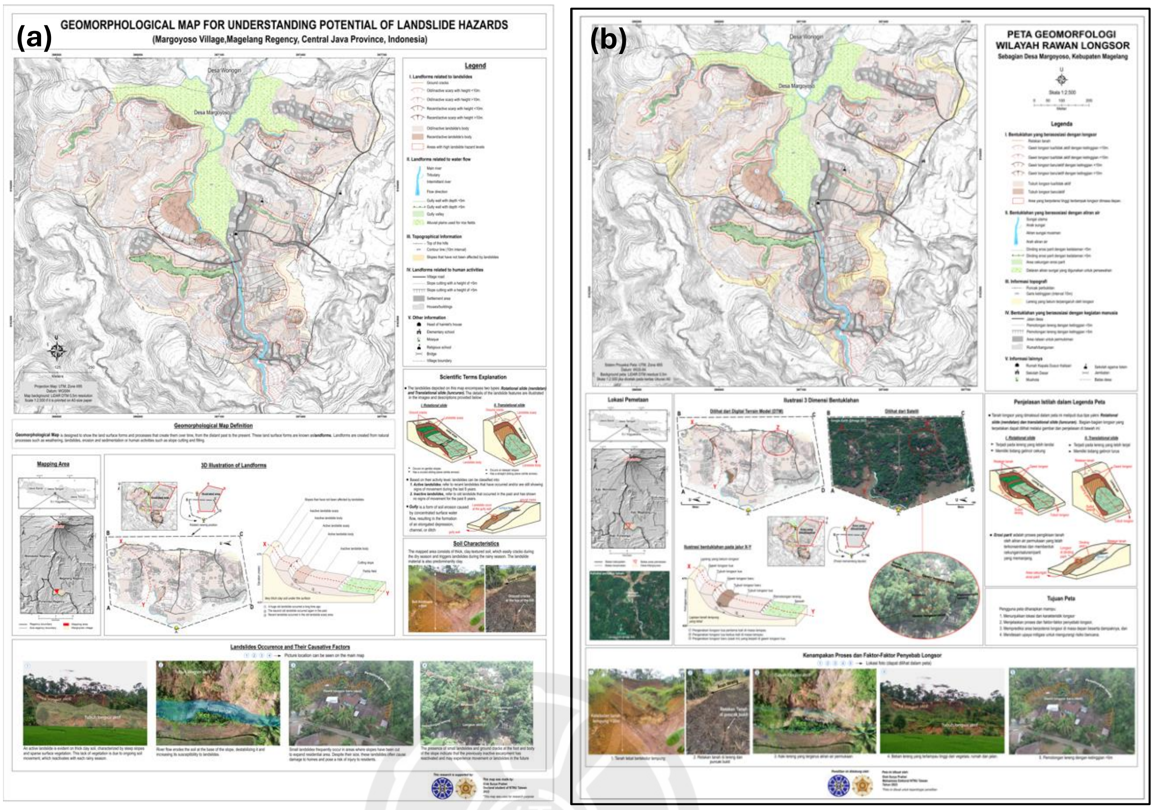


Figure 4.9 The comparison of the derivative geomorphological map before and after the adjustment process. a) The first draft. b) The revised version. (See supplementary data 2 and 5 for the actual size)

4.2.3. Final map result

The feedback gathered from the supporting team, which included professionals from diverse fields as well as map users, played a crucial role in refining the design of the Visual Storytelling Geomorphological Map (VSGM). Each piece of feedback was carefully considered to ensure that the map effectively met the needs and expectations of its intended audience. After making the necessary adjustments based on this input, the revised version of the map was presented to the supporting team for further review. This step was essential to validate that the revisions addressed all concerns and achieved the desired improvements. Only after the team confirmed that the revised map met their standards, and no additional feedback was provided did the map become finalized. The final version of the VSGM (see the supplementary folder) was thus the result of a thorough, collaborative process, ensuring that it was well-suited for its purpose and audience.

4.3. Discussion

The co-production technique played a crucial role in shaping the final design of the Visual Storytelling Geomorphological Map (VSGM), ensuring it not only aligned closely with user needs but also maintained the quality of map design. By involving professionals and target users throughout the design process, the VSGM was enriched with diverse insights, making it more practical and user-friendly. Iterative feedback loops allowed for continuous refinement, ensuring the geomorphological map addressed real-world challenges faced by disaster communicators. As a result, the final VSGM is a well-rounded tool that reflects both expert knowledge and the specific needs of its users, highlighting the effectiveness of co-production in creating relevant and functional solutions.

4.3.1. The role of the multidisciplinary professionals in designing VSGM

In this research, the multidisciplinary professional's involvement in the co-production mapping played a significant role in shaping the final design of the Visual Story-Based Geomorphological Map (VSGM). Given that the development of a map itself is inherently multidisciplinary, which includes a spectrum of diversity in data, users, and problem context (Griffin, Robinson, et al., 2017), it is crucial for geomorphologists to recognize the importance of collaboration with other experts. Involving experts from diverse fields, such as cartography, disaster management, geography education, learning media, and design illustration, proved invaluable in identifying areas of the VSGM that required improvement, ultimately enhancing its effectiveness as a communication tool.

According to the professional's involvement in the co-production of the VSGM, several key points must be emphasized in each section of the prototype. First, for the derivative geomorphological maps, a geography education expert recommended explicitly stating the map's objectives and placing them in a dedicated frame within the map layout. This approach helps users understand the scope of the information they should acquire when using the map. This idea aligns with the theory of goal setting in education, which posits that informing specific, measurable, and achievable learning objectives can motivate users and improve learning outcomes by enabling them to track their progress (Latham & Locke, 2007; Morisano et al., 2010).

For the instruction sheets, learning media experts suggested making them more concise by reducing complex technical explanations, using a simple numbering format, and adding symbols or icons that directly reference the main geomorphological map. These adjustments would make the instructions easier to follow by non-expert users. Morrison et al., (2020) also emphasize that effective instruction sheets should take into account the characteristics of the learner, provide easy-to-follow guidance to convey the message clearly using straightforward language, avoid large blocks of text, and follow a logical sequence that integrates seamlessly into the user's workflow.

In the comic section, disaster management experts proposed featuring the map user as the main character, with their challenges as a disaster communicator forming the central conflict of the story. Meanwhile, design illustrators stressed the importance of creating visually engaging comic illustrations that effectively convey the narrative. This concept is supported by research showing that incorporating local cultural elements and character values into storytelling can make the content more relatable and impactful. Moreover, the quality of both the illustrations and the narrative is crucial to the success of comics as an educational medium (Issa, 2018).

The findings of this chapter reinforce the value of the co-production approach, in line with previous research that emphasizes the importance of interdisciplinary collaboration in improving the clarity and usability of disaster-related maps. Vollstedt et al., (2021) demonstrated how the involvement of journalists and coastal experts can enhance the linguistic quality and clarity of flood hazard maps, making them more accessible to local communities. Similarly, Driedger et al., (2024) illustrated how volcanologists, working alongside cartographers, design illustrators, and national park officers, were able to simplify volcano hazard maps to ensure they were easily comprehensible for non-expert audiences. Likewise, Luke et al., (2018) emphasized the significance of collaboration between social scientists and engineers in redesigning flood hazard maps to better align with the needs of flood risk management. These studies, along with the present research, highlight how interdisciplinary collaboration can enhance the design quality of disaster-related communication tools, making them more effective and user-friendly.

4.3.2. The role of the map users in designing VSGM

Although the involvement of other professionals is beneficial in improving the quality of the VSGM design, feedback from map users is paramount and cannot be ignored. It is because the effectiveness of information visualization tool including map is ultimately determined by the end users experience (Lam et al., 2012). The main function of involving map users before the finalization of the VSGM process is to ensure that the core objectives of the map are aligned with the users' needs and expectations. Without user feedback, even a map with strong technical merits runs the risk of not resonating with its intended audience or failing to sufficiently address their concerns (Roth et al., 2015). Based on the interviews with map users, there were no objections or negative feedback regarding the four main objectives of the VSGM, suggesting that these objectives were well-aligned with the users' needs.

User feedback also provides valuable real-world insights into how a communication design will be utilized in practice, highlighting usability issues that professionals might overlook from their specialized perspectives (Følstad et al., 2016). For instance, while cartographers and geomorphologists may focus on aspects like the accuracy, symbol colour balance, and completeness of information, users often identify more practical concerns, such as excessive content, difficulty in navigating the map, or challenges in interpreting specific symbols or legends. In this study, although users appreciated the overall objectives and visual design of the VSGM, they expressed frustration with the lengthy text explanations in the instruction sheets, which made them harder to follow. Additionally, they noted that the lack of contrast in the symbols' colouring on the geomorphological map made it difficult to distinguish between them. These criticisms are crucial for improving the map's usability. Such feedback not only enhances the technical robustness of the final design but also ensures it remains user-friendly and accessible to its intended users.

The researcher acknowledges that this pilot study cannot make the VSGM a perfect tool. Considering the diverse backgrounds and varying levels of map-reading skills among the target users, as well as their different experiences as landslide communicators, perfection is an unrealistic goal. Instead, the primary purpose of involving users in the development process is to identify and mitigate potential challenges they may encounter when using the map. By gathering feedback from users with different perspectives, the study seeks to address common usability issues and refine the map so that it becomes a more effective tool in real-world scenarios. This user involvement process helps to create a map that is not only technically sound but also accessible and practical for the intended users.

4.3.3. Insights on the benefits of co-production in geomorphological map popularization

The rapid advancement of geoscience technology, particularly in remote sensing and GIS, has greatly facilitated the creation of detailed geomorphological maps, which are crucial for the sustainability of natural space including enhancing understanding on natural hazard and disaster risk management (Alcántara-Ayala, 2002; Mukherjee, 2023). However, this increased complexity also presents a challenge: how to make these maps accessible and useful to a broader audience, such as landslide communicators who are not geomorphologists (Griffiths & Abraham, 2008b; Smith et al., 2011). This challenge underscores the need for research focused on developing geomorphology map designs that can be easily understood by non-experts, enabling them to grasp hazards and risks effectively and apply this knowledge to design clearer and more actionable landslide mitigation strategies. Therefore, user involvement, along with collaboration from professionals in various fields, is essential to create a user-friendly map and bridge the gap between complex geospatial data and real-world application.

This study is the first to apply the co-production method to the creation of visual story-based geomorphological maps specifically aimed at landslide risk communicators in Indonesia. The differences in scientific context, intended messages, and target users introduce distinct challenges in the map design process (Griffin, White, et al., 2017). This study makes a valuable contribution by using co-production approach to highlight key aspects that are often overlooked by geomorphologists when attempting to make geomorphological maps more accessible for landslide risk communication in Indonesia through the use of visual storytelling techniques.

These research findings reinforce the notion that the co-production method can serve as a great option for geomorphologists to popularize geomorphological maps, complementing other widely used approaches such as participatory mapping. Participatory mapping, which promotes user involvement in the map design process, sometimes requires compromising data accuracy and visualization standards due to non-experts users' limited mapping skills and understanding about the scientific content (Pratiwi et al., 2023). However, a co-production approach—fostering close collaboration not only between scientists and map users but also among scientists from different disciplines—creates opportunities to uphold the map's quality in terms of accuracy and design while ensuring it remains user-friendly and easily understandable for the non-expert map users.

Chapter 5 - Results: Cartographic Quality of The VSGM Design

5.1. General overview of the usability results

The cartographic quality of VSGM has been successfully pictured through usability evaluation (see Appendix 2). Usability testing with eight respondents reveals that the VSGM prototype is generally user-friendly for the target audience (Figure 5.1). All respondents correctly answered three questions without needing expert help, while one or two respondents required assistance with three other questions. However, one question posed a greater challenge, where only three out of eight respondents answering it correctly without assistance.

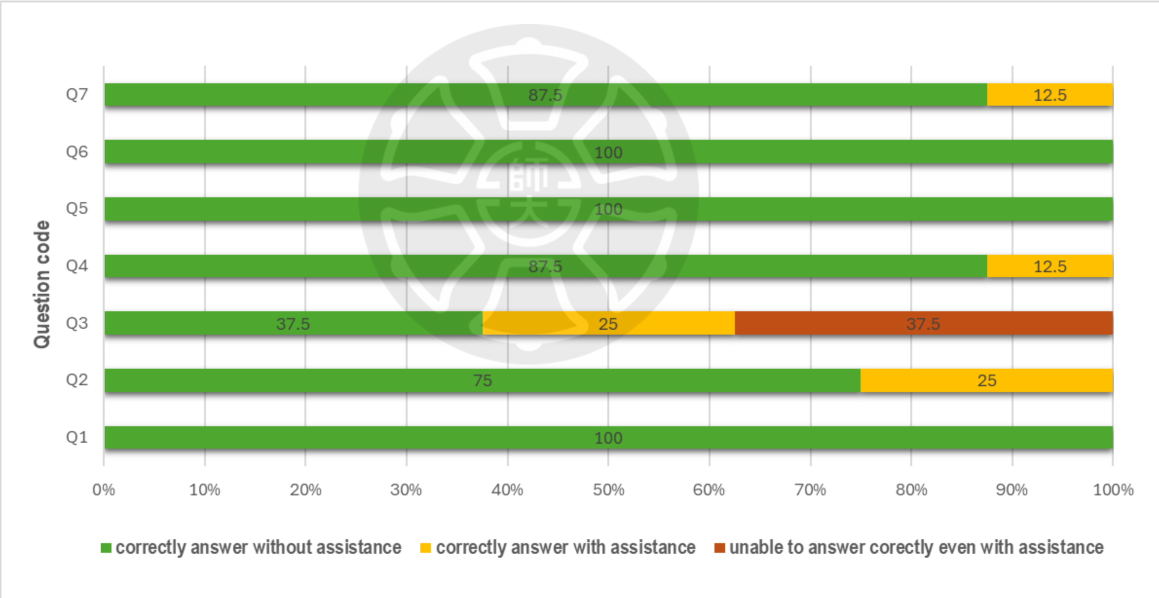


Figure 5.1 The percentage of respondents categorized based on how they responded to the interviewer's questions.

5.1.1. User success in using the VSGM

Identifying landslide locations (Q1) on the geomorphological map was the first easy task for all users. They easily interpreted symbols representing landslide-related landforms, such as scarps, landslide bodies, and ground cracks. Additionally, users could distinguish variations in scarp height, as demonstrated by respondent [R4] from BPBD. The clarity of the map's symbols and details enabled users to accurately identify and assess these features, indicating the map's effectiveness in communicating key geomorphological information.

"*Yes, I can identify landslide's location in this map. This is landslide's body (pointing active and inactive landslide's body symbols). This one is landslide' scarp (pointing active and inactive landslide's scarp symbols). I can distinguish the scarp based on its height. This is scarp area with a height of more than 10m while this one is less than 10 meters*" said respondent [R4]

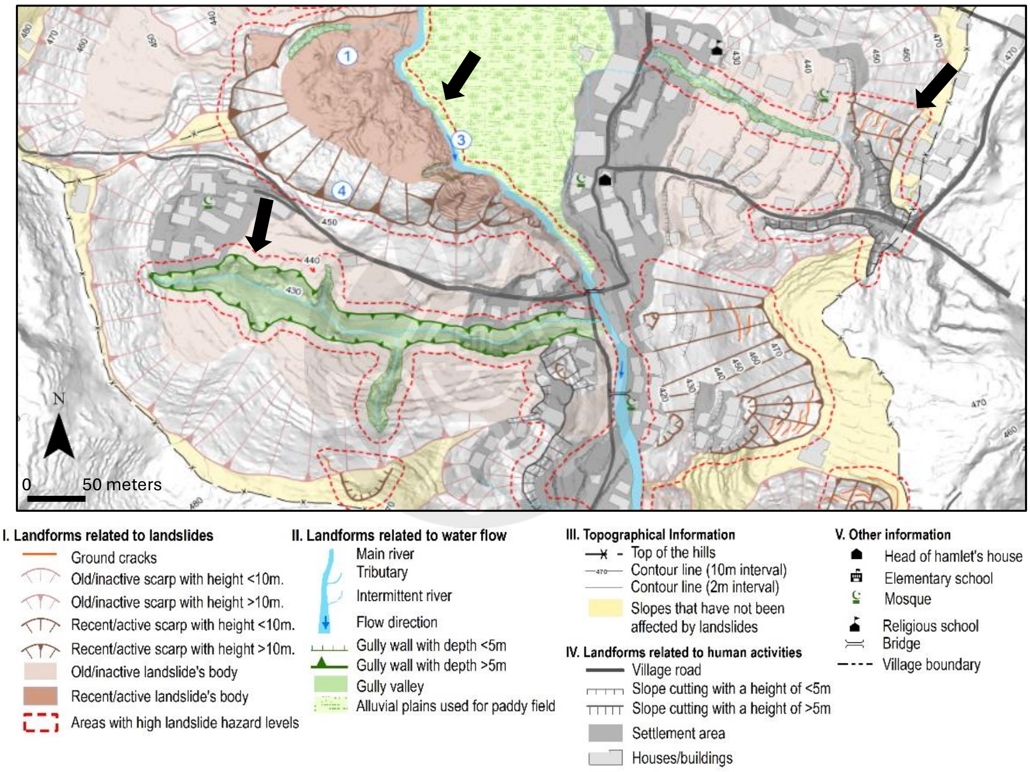


Figure 5.2 An illustration showing how respondents can identify areas with a higher potential to landslide in the future by referencing the red dashed symbol, as indicated by the black arrow. (See the full version of the map on the supplementary data 5)

Pointing out the landslide hazardous area (Q5) was the second task that all users completed correctly without expert assistance. They accurately identified areas with a higher potential for future landslides by referring to symbols in the map legend (Figure 5.2). Users could also explain why certain locations were more likely to experience future landslides than others. For example, respondent

[R7] from an NGO noted that areas near active landslides are more likely to move again, while respondent [R3] from BPBD highlighted soil cracks as a key factor. Additionally, respondent [R8] from an NGO explained that slopes facing rivers or gullies are also more susceptible to future landslides because the surface flow can erode the base of the slope over time, weakening it and potentially leading to instability and collapse.

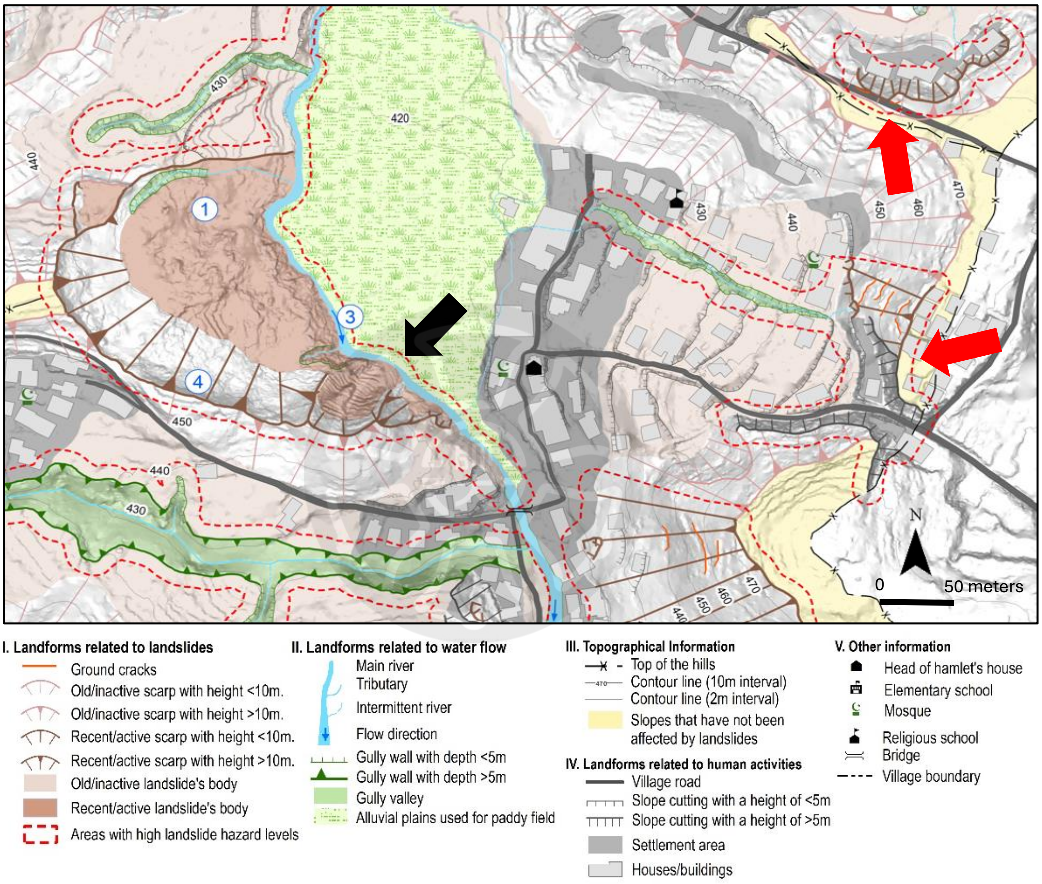


Figure 5.3 An illustration depicting how [R7] utilizes the VSGM to identify areas with high and low landslide risks. The red arrows highlight areas at higher risk due to the presence of settlements and roads within active landslide zones, whereas the black arrow points to areas at lower risk, where any landslide would primarily impact agricultural land. (See the full version of the map on the supplementary data 5)

Using the geomorphological map to identify high-risk landslide zones (Q6) was the third task that all users successfully completed without expert assistance. Generally, users identified high-risk zones as high potential landslides area that are located near settlements, road networks, or public facilities. For instance, respondent [R2] from BPBD pointed out an active landslide area that close to residential zones or where active landslides threaten road networks are the most at risk. Respondent [R7] added that the detailed geomorphological map greatly aided in predicting the impacts of potential landslides, allowing him to classify areas as high or low risk based on the presence of vulnerable elements nearby (Figure5.3).

Identifying landslide activity on the map (Q2) was a relatively easy task for users, though two respondents required expert assistance. This task involved recognizing two levels of landslide activity—inactive and active—and locating them on the geomorphology map. While most users easily identified and located these activities, respondent [R8] from an NGO and respondent [R2] from BPBD faced some difficulty. Respondent [R8] hesitated initially due to uncertainty about the term "landslide activity," but with guidance, she quickly understood. Respondent [R2] challenge stemmed from difficulty distinguishing the colours representing inactive and active landslides. Despite these challenges, both respondents were ultimately able to correctly identify the landslide activities on the map with minimal assistance, demonstrating that the geomorphology map was generally effective for most users, even if some required additional clarification.

Although one respondent required expert assistance, most users found the task of explaining the factors causing landslides in the mapping area (Q4) relatively easy. In this task, users were asked to explain the factors causing landslides based on several photographs taken at the mapping site, each accompanied by a brief explanation. These visual aids helped them confidently identify natural factors such as thick, cracked clay soil, proximity to rivers, and heavy slope mass due to vegetation or water content. They also recognized unsafe slope-cutting activities as a non-natural factor. Respondent [R8] from an NGO was initially less confident in explaining how slope cutting could lead to landslides, but with some expert clarification, she quickly understood the connection.

Designing landslide mitigation efforts (Q7) using the VSGM was relatively easy for most users, with only one requiring minor expert assistance. The detailed geomorphological map significantly aided users in identifying effective locations for installing Early Warning Systems (EWS), hazard signs, and slope reinforcement embankments. Respondent [R5], from BBPD, said that EWS would be more effective at point A than at point B due to the higher density of settlements around point A. Additionally, respondent [R6] from an NGO used the geomorphological maps to recommend optimal locations for building slope embankments, particularly to prevent landslides caused by river erosion and cutting slope activity. An illustration of how respondent [R5] and respondent [R6] used VSGM to design landslide mitigation measures is shown in Figure 5.4.

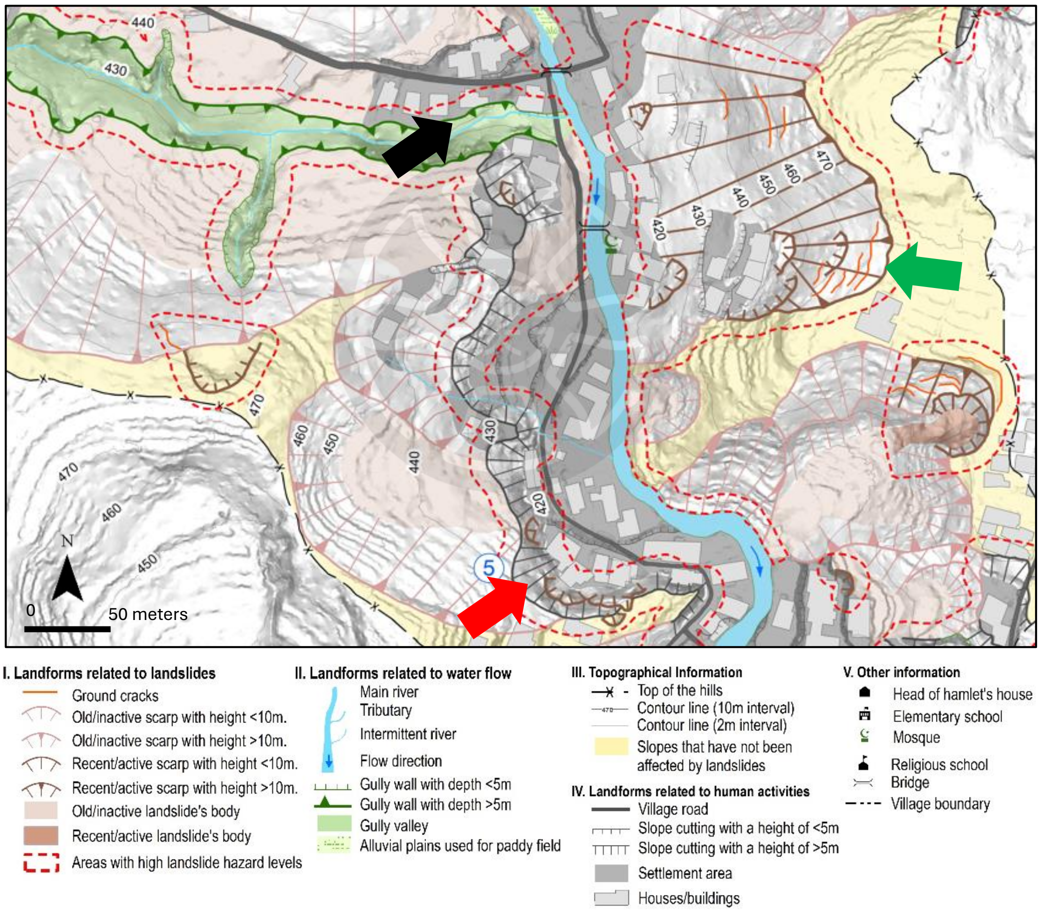


Figure 5.4 An illustration depicting how respondents utilize the VSGM to design mitigation actions. The red arrow and black arrow indicate locations recommended by [R6] for the construction of slope reinforcement around the cutting slope and gully slope, respectively, while the green arrow marks the locations suggested by [R5] for installing an Early Warning System (EWS). (See the full version of the map on the supplementary data 5)

5.1.2. User obstacles in using the VSGM

Explaining the types of landslides that commonly occur in the mapping area (Q3) proved to be the most challenging task for respondents using the VSGM. Even after experts guided them to the relevant information on the map, three respondents were unable to correctly identify and explain the two types of landslides: translational and rotational. Despite the researchers providing illustrations and bullet points highlighting the differences, comprehension remained difficult (Figure 5.5). For instance, respondent [R4] from BPBD admitted he still did not understand what a rotational slide meant after viewing the illustration, and respondent [R8] from an NGO mentioned that she was unaware landslides could be classified into different types.

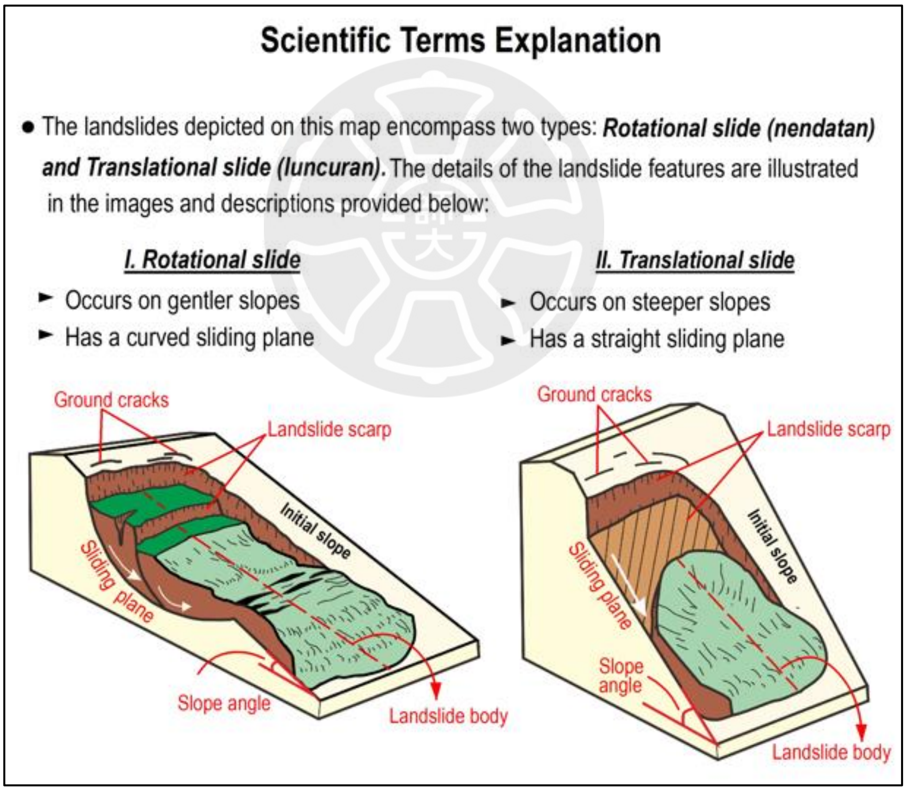


Figure 5.5 Visualization of landslide types using sketches in the VSGM, which respondents found difficult to understand.

Although two respondents initially struggled to explain the types of landslides, they were able to answer correctly with some expert assistance. Respondent [R6] from NGO was unsure about the concept of landslide types, but after the researcher directed him to the instruction sheet, he quickly understood. Similarly, respondent [R5] from BPBD found it challenging to differentiate between the two types of landslides, even after viewing the pictures. However, when prompted to consider the shape of the slip plane, he correctly explained that rotational slides involve a concave slip plane, while translational slides have a straight one.

5.2. Discussion

This usability evaluation confirms that the VSGM exhibits a satisfactory quality of cartographic design, allowing users to efficiently navigate the map and recognize its objectives. Although a small number of respondents experienced difficulties or required assistance with specific tasks, the majority successfully completed them without expert intervention. The integration of a comic-based introduction and guided map-reading through an instruction sheet effectively supports users in understanding the four key messages embedded in the geomorphological map. The successful identification of these messages suggests that users are not only capable of recognizing landslide hazards but also of utilizing the map for application purpose such as designing mitigation strategies. These findings contribute to give empirical evidence on the success of VSGM as an approach to retain geomorphological detail while ensuring accessibility for non-expert user.

5.2.1. Impact of geovisualisation technique on the map usability

Despite the success of the VSGM in making complex geomorphological information more accessible, certain aspects still require improvement. The evaluation results highlight that explaining landslide types through illustrated sketches with bullet points (Q3) remains a significant challenge for respondents. While illustrated sketches have advantages, such as simplifying information and minimizing distractions from the main message (Krasnoryadtseva et al., 2020; Wiley, 2019), they were not as effective in this study. The sketches may have lacked the real-world visual context (Ganea et al., 2008) needed to clearly convey the differences between translational and rotational slides, making it harder for respondents to grasp the information.

Including photos of both types of landslides alongside the sketches may enhance the usability of future maps. In this study, real field photos proved effective in helping respondents explain the causative factors of landslides (Q4), with only one respondent needing minor assistance. This suggests that incorporating real-world images is benefits for understanding natural phenomena and geographic features. Several studies support this approach, showing that real-world photography can enhance learning by providing visual context, promoting engagement and facilitating a deeper understanding of geographic concepts (Fraile-Jurado et al., 2019; Henderson & Rickard, 1972).

5.2.2. A well-design VSGM leading to higher cognitive learning

While respondents may struggle with understanding some scientific terms, such as landslide types, they demonstrate a surprising ease in applying geomorphological maps for practical purposes. They effectively use maps to explain identify high-risk zones and design mitigation efforts. If we refer to the Bloom's Taxonomy, a framework that categorizes cognitive learning from basic knowledge to higher-order thinking (Krathwohl, 2002), the VSGM design successfully enables users to reach the higher cognitive levels of application, where they can use information to solve real-world problems (Figure 5.6) This suggests that the VSGM design not only makes scientific information more understandable but also empowers users to engage in practical, solution-oriented thinking.

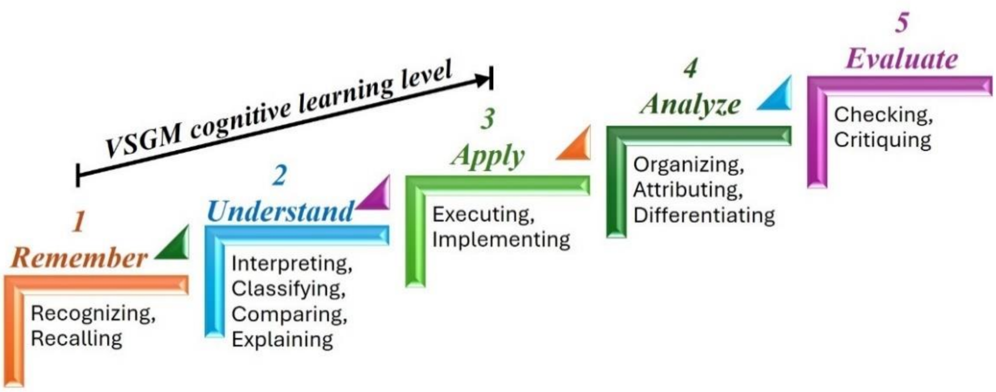


Figure 5.6 Level of VSGM cognitive learning represented within Bloom's Taxonomy hierarchy.

The VSGM design represents a significant advancement in landslide risk communication by addressing practical needs beyond merely facilitating information comprehension. While many landslide-related maps have focused primarily on enhancing users' understanding of landslide phenomena by providing scientific information such as geological map and slope map presented by (Alcántara-Ayala et al., 2018) and (Setiawan et al., 2021), the VSGM design goes further by equipping users with tools to apply this knowledge in real-world contexts. This approach leads to more positive learning outcomes as it engages higher cognitive processes (Kumpas-Lenk et al., 2018; Kurtuluş & Ada, 2017).

The success of the VSGM in fostering advanced levels of cognitive learning among users can be directly attributed to the sophisticated cartographic quality allowing user-friendly interface design. First, the comic element plays a pivotal role by providing a compelling narrative that introduces users to the practical utility of geomorphological maps in addressing real-world challenges faced by landslide communicators. This storytelling technique not only captures users' attention but also sparks their curiosity, motivating them to explore how the map can function as a practical tool, as illustrated in the story.

Second, the inclusion of instruction sheets guides users through a structured process, ensuring they follow the map's intended flow. This step-by-step guidance allows users to intuitively apply the map to identify high-risk areas for landslides and develop mitigation strategies. Without explicit instruction, users are seamlessly led to achieve the application level of cognitive learning—demonstrating their ability to not only understand but also implement the information presented.

Finally, the vivid and high-quality visual representation of the geomorphological map, enhanced by cutting-edge topographical data such as LiDAR and UAV aerial imagery, further solidifies the map’s effectiveness. The combination of accurate data and illustrative detail helps users grasp the environmental conditions of the mapped area, even if they have never visited it. This sophisticated visualization significantly reduces the cognitive load, making it easier for users to interpret complex information. Ultimately, the strong visual appeal and clarity of the VSGM make it a powerful tool for not only communicating landslide risks but also empowering users to apply this knowledge effectively in real-world scenarios.

5.2.3. Insights on the retaining geomorphological detail while ensuring map usability

Previous studies, such as (Griffiths & Abraham, 2008a), have recommended simplifying geomorphological maps into landslide hazard maps by reducing the amount of detailed geomorphological information. The rationale was that such complexity might overwhelm non-experts in using the map and understanding the map intended messages. Since then, landslide hazard and risk maps have become the preferred tool for disaster risk communication tools with communities as has been the case in various countries like Mexico (Alcántara-Ayala et al., 2018), Peru (Klimeš et al., 2019), and Indonesia (Karnawati, Fathani, Wilopo, & Andayani, 2018). While these maps offer information about hazard and risk level, their effectiveness in improving understanding on hazard and risk as well as facilitating to think about concrete actions for reducing landslide risk remains uncertain.

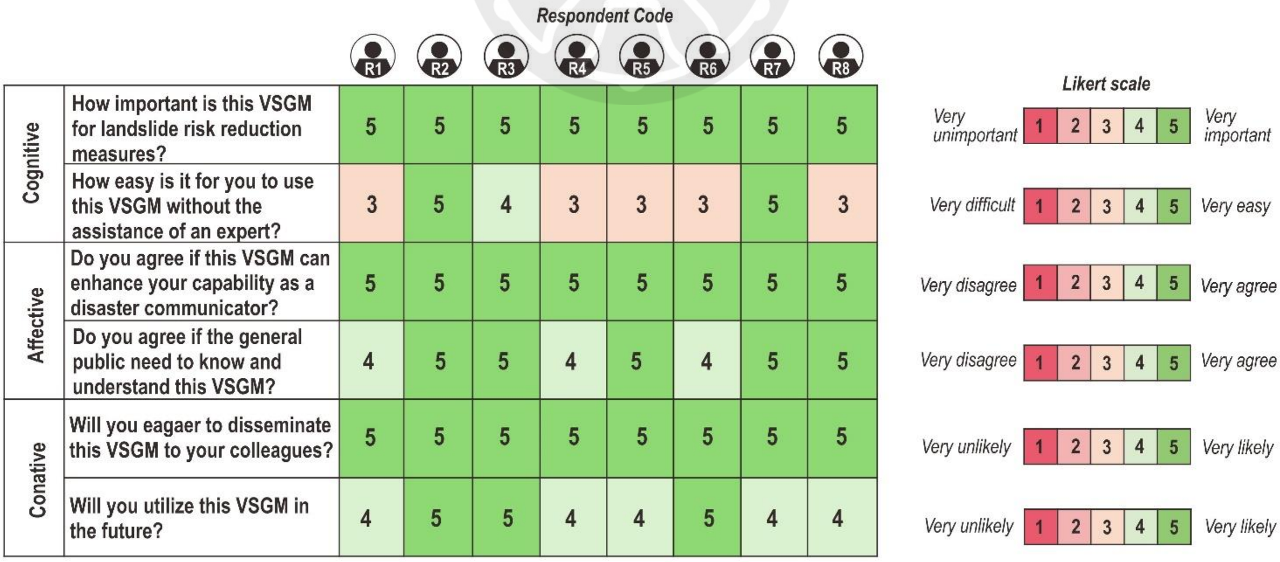
While previous research suggested that non-experts might struggle with detailed geomorphological information, our findings show that a well-designed visual storytelling approach has a good usability level and even can empower non-experts to effectively engage with and use this complex information. Unlike the simplified landslide hazard maps recommended in earlier research, our VSGM design retains more geomorphological details while still being accessible to non-experts. One possible explanation for this difference is that previous studies did not incorporate visual storytelling techniques that guide users through complex information. By integrating narrative elements and clear visual cues, this VSGM design may help users better understand and use the geomorphological data for application purpose, something that previous map designs may have lacked.

The comparison with previous studies also suggests that simplifying geomorphological maps may not always be necessary. Instead, a design that combines detailed information with effective visual storytelling techniques offers a more balanced approach, making geomorphological maps both informative and applicable to non-experts. This insight could guide future research and the development of more advanced disaster communication tools. More importantly, this research could inspire the geomorphological community to develop more innovative map designs that enhance the visibility and value of geomorphological maps in the public's eyes.

Chapter 6 - Results: Users' Perception of The VSGM Design

6.1. General overview of the users' perception

An overview of user perceptions of the VSGM can be observed through the trends in the Likert scale results provided by respondents for each interview question (Figure 6.1). While some felt that VSGM had a moderate level of ease of use, all respondents agreed that it plays a very important role in landslide risks reduction countermeasures. VSGM also succeeded in building a positive image of the geomorphology map, as all respondents strongly agreed or agreed that this map could improve their abilities as disaster communicators and should be understood by the public outside the geoscience community. Furthermore, all respondents indicated they were very likely or likely to participate in disseminating and using VSGM in the future. To understand why these perceptions are formed, the cognitive, affective, and conative dimensions of respondents are described based on the thematic analysis of their open-ended responses shown in this following sub-chapters.



Dimension	Question	R1	R2	R3	R4	R5	R6	R7	R8
Cognitive	How important is this VSGM for landslide risk reduction measures?	5	5	5	5	5	5	5	5
	How easy is it for you to use this VSGM without the assistance of an expert?	3	5	4	3	3	3	5	3
Affective	Do you agree if this VSGM can enhance your capability as a disaster communicator?	5	5	5	5	5	5	5	5
	Do you agree if the general public need to know and understand this VSGM?	4	5	5	4	5	4	5	5
Conative	Will you eagaer to disseminate this VSGM to your colleagues?	5	5	5	5	5	5	5	5
	Will you utilize this VSGM in the future?	4	5	5	4	4	5	4	4

Likert scale

	1	2	3	4	5	
Very unimportant	1	2	3	4	5	Very important
Very difficult	1	2	3	4	5	Very easy
Very disagree	1	2	3	4	5	Very agree
Very disagree	1	2	3	4	5	Very agree
Very unlikely	1	2	3	4	5	Very likely
Very unlikely	1	2	3	4	5	Very likely

Figure 6.1 The general overview of the respondents' perceptions about VSGM based on the Likert scale.

6.1.1. Cognitive dimension

The cognitive dimension explored in this research focuses on respondents' knowledge respected to VSGM, as reflected in their perceived usefulness and ease of use. The perceived usefulness was determined through thematic analysis of their responses to questions about why they believe VSGM plays a crucial role in landslide risk reduction (see Appendix 3 and Appendix 4). Meanwhile, the perceived easy to use was identified through thematic analysis of their answers regarding factors influencing their confidence in using the maps without expert assistance (see Appendix 5 and Appendix 6). The results of thematic analysis of both perceived usefulness and easy to use were shown as items in Table 6.1.

Table 6.1 Cognitive dimension, sub-dimensions and their items

Dimension	Sub-dimension	Items
Cognitive	Perceived usefulness	1. This map can show the locations and characteristics of landslides more clearly. 2. This map provides an explanation of the factors causing landslides. 3. This map is useful for understanding potential landslide hazards and their impacts. 4. This map is useful for designing mitigation efforts to reduce the disaster risk
	Perceived easy to use	1. The comic is like a prologue that helps to set the stage before diving into the map.* 2. The map reading instructions are easy to follow.* 3. The 3D illustration and photos on the main map aid in visualizing the realistic representation of topographic and geomorphic features.* 4. Several training sessions are needed to master the map.** 5. More detailed explanations about the terms on the map are still required.**

* Statements indicating that the VSGM is easy for users to navigate and understand
** Statements indicating that the VSGM is difficult for users to navigate and understand.

6.1.1.1. Perceived usefulness

After using VSGM, respondents mentioned at least four items that demonstrate the usefulness of geomorphological maps. This knowledge of VSGM's benefits reinforced their belief in the crucial role of geomorphological maps for the success of landslide risk reduction programs. The perceived usefulness of the map also aligns with the substantive objectives intended to be delivered. The following items presents how respondents' statements demonstrate their understanding of the four functions of geomorphological maps.

1) **This map can show the locations and characteristics of landslides more clearly.**

   The first benefit of VSGM, as reported by respondents, is its ability to precisely and accurately show the location and characteristics of landslides.

   "Beside it allows me to see the distribution and locations of landslides, this map is very useful for showing the actual forms of landslides, such as their scarp and the bodies." said respondent [R3].

   In this 1:2500 VSGM, landslide features are represented using area symbols, which makes it easier for users to visualize their position, shape, and dimensions in the real world compared to point symbols. Additionally, respondents gained new knowledge that landslides can be categorized based on their activity level. Respondent [R1], noted that information about the level of landslide activity is something new for her that can help to assess the likelihood of an area experiencing future landslides.

   "From this map I could see the landslide locations and their characteristics, such as which ones were still active, and which were no longer active. I believe classifying the level of landslide activity like this will make it easier for me to identify which areas are more prone to future

landslides. Naturally, areas around active landslides are more likely to continue moving compared to those that have been inactive for a long time" said respondent [R1].

2) This map provides an explanation of the factors causing landslides.

The second benefit of VSGM, as perceived by respondents, is its ability to explain the factors causing landslides in the mapped area. Landslides, being geomorphic processes, can be triggered by various natural and human factors. The complexity of these factors was often unknown to respondents. After using VSGM, most respondents felt that their understanding of the causes and triggers of landslides had improved. Respondent [R8], from the NGO, was among those who experienced this increase in knowledge.

"*After reading this map, I learned a lot about what causes landslides. Before, I thought landslides only happened because of elevation and slope. But now I know there are many factors influencing them, like thick clay soil that cracks easily, river flows eroding the base of the slope, or people cutting into the slope without careful planning and calculation"* said respondent [R8].

3) This map is useful for predicting potential landslide hazards and their impacts.

The third benefit of VSGM, as mentioned by all respondents, is its effectiveness in assessing the level for landslide hazards and the likely impact of losses. The information on landslide activities shown in VSGM successfully provides users with an understanding of when the last landslide occurred. Active landslides, which have been detected within the last 8 years, indicate that the surrounding area has greater potential to move again in the near future compared to areas around old landslides, where no activity has been detected for over 8 years. Respondent [R7], from an NGO, was one respondent who recognized this advantage.

“I think if we could accurately map the location and activity level of landslides like this, it would be very useful for assessing which areas are at greater potential for landslides in the future. For instance, we need to be more cautious of active landslides which recently shown movements compared to old ones that haven't moved in a long time” said respondent [R7].

VSGM is also able to describe the dimensions of slopes, and parts of landslides in more detail, making it easier for users to analyze how big the magnitude of landslides might occur in the future. When the magnitude of the landslide can be identified, then how big the impact that might be suffered can also be predicted. One of the respondents who conveyed the benefits of VSGM was respondent [R3] from BPBD.

“The information about the height and area of slopes prone to landslides provided in this map is crucial for estimating how big a landslide could be and how far it might travel. So that, it helps us identify which houses, roads, or other assets are likely to be affected by landslides in the future” said respondent [R3]

4) This map is useful for designing mitigation efforts to reduce the disaster risk

The primary function of VSGM, widely recognized by all respondents, is its crucial role in designing landslide disaster mitigation strategies. They believe that geomorphological maps are essential because the comprehensive information they provide can guide effective mitigation steps to reduce landslide hazards and risks. Respondents noted that VSGM is useful for both structural and non-structural mitigation planning. For example, respondent [R4], from BPBD, explained why he believes VSGM is crucial for designing structural mitigation or any kind of infrastructure-based efforts.

"*Yes, this map is very important, because if we understand the potential disasters in our area, such as knowing the types of threats and their locations, then we can take mitigation or anticipatory measures to reduce their impact. For example, we can determine where to place slope retention walls and Early Warning Systems (EWS) to reduce landslide risk"* said respondent [R4].

Several respondents also shared their views on the role of VSGM in non-structural mitigation, including policy, planning, education, and awareness measures to reduce disaster risk. For example, respondent [R1], from BPBD, argued that VSGM is a crucial scientific resource for spatial planning in landslide-prone areas. She said that the map provides an idea of slopes with a higher potential for landslides compared to those that are relatively safer, therefore, this comprehensive data is very important for determining suitable residential zones and areas that should be avoided for central development. Respondent [R5], from BPBD, also agreed that geomorphological map plays a crucial role in designing disaster risk reduction policies, particularly through land and forest conservation efforts.

"……Moreover, it can serve as a guide for environmental initiatives to carry out land conservation and reforestation that can reduce the risk of landslides. So that with geomorphological maps, all disaster risk reduction activities can be carried out based on actual data" said respondent [R5].

6.1.1.2. Perceived easy to use

Most respondents considered VSGM to be of moderate difficulty, neither too easy nor too hard to use. This is evidenced by five out of eight respondents selecting a 3 on the Likert scale for questions related to perceived ease of use.

There were at least three statements indicating that VSGM is easy for respondents to navigate and understand (items 1 to 3). Conversely, there were two statements suggesting that VSGM is difficult for users to navigate and understand (items 4 and 5).

1) **The comic is like a prologue that helps to set the stage before diving into the map.**

   The first reason VSGM is considered easy to use is the inclusion of a comic that is recommended to be read before using the main map. Respondents view the comic as a prologue that helps set the stage before diving into the geomorphological map. Respondent [R1], from BPBD, said, "When I checked out the comic, I could already guess what I was going to learn." The story in the comic provides respondents with information about what a geomorphology map is, why it is important, and how it can be used to address common challenges in landslide mitigation efforts. One of respondents who found it easy to use was respondent [R2], from BPBD.

   "This comic seems to provide strong reasons why we should use geomorphological maps……... So, by reading this comic, we become even more eager to understand geomorphological maps because these maps can address common problems encountered in disaster risk reduction measures" said respondent [R2]

   Respondent [R5], from BPBD, also acknowledged that the illustrations in the comic effectively conveyed the story and significantly helped him understand the scientific terminology often discussed in landslide mitigation. His colleague respondent [R3], from BPBD, supported this view, stating that the comic serves as a pocket guide that users must read and understand before using the geomorphology map.

   "For users who are already familiar with landslide terminology, this comic may not be too important. However, the reality is that many

disaster educators are not yet familiar with specific disaster terms, especially those related to landslides. So, in my opinion, this comic needs to be read well in advance before reading the Geomorphological Map" said respondent [R3].

2) **The map reading instructions are easy to follow.**

The second factor contributing to VSGM's ease of use is the inclusion of clear map reading instructions. These instructions provide a step-by-step guide for reading the map, enabling users to navigate it independently without expert assistance in the future. Half of the respondents explicitly stated that the instruction sheet really helps them in using VSGM. Respondent [R7], from the NGO, was one respondent who acknowledged this benefit.

"If the map is the same as this one and I follow the previous instructions, I'm sure I can use it myself. The map is easy to use and understand because it includes comics and clear instructions" said respondent [R7]

3) **The 3D illustration and photos on the main map aid in visualizing more realistic representation of topographic and geomorphic features.**

The third factor that makes VSGM easier for respondents to use is the incorporation of 3D illustrations and photos on the main map. LiDAR DTM enables map makers to present topography and landforms more realistically, while oblique photos taken with drones accurately depict land cover conditions in the field. Respondent [R6], from an NGO, mentioned that visualizations close to reality help him understand newly learned geomorphic features, such as old and young landslide scarps, soil cracks, or gully erosion. Respondent [R7], respondent [R6]'s colleague, also praised the benefits of 3D visualization and photos on the main map.

"The 3D visualization on the main map makes it easier for me to understand the topographical features. I can imagine the shape of the landslide and the terrain at the mapping location, including the rivers and the size of the landslides, even without having visited the area before" said respondent [R7].

4) **Several training sessions are needed to master the map.**

The first factor contributing to the moderate perceived ease of use for VSGM is that most respondents felt they still needed several training sessions or practice to use the map without expert assistance. Despite being able to follow the map instruction sheet, respondents lacked confidence in using it independently in the future. Respondent [R4], from BPBD, noted that VSGM is a map that cannot be fully understood with just one try. He mentioned that after studying the map once or twice, he might not be fully capable of using it on his own, but with a few more training sessions and detailed explanations, he could manage it in the future. Respondent [R8], from an NGO, shared a similar view.

"*I'm not entirely sure I can use the map without assistance from an expert yet. I feel capable because I can understand how to read the map. I feel incapable because there are still some terms that are unfamiliar to me, and I've just learned about them now. So, I'm a bit less confident if asked to explain again. Basically, I still need time to learn more*" said respondent [R8]

5) **More detailed explanations about the terms on the map are still required.**

The second factor contributing to the moderate perceived ease of use for VSGM is the lack of detailed explanations for several scientific terms and the meanings of the images or illustrations displayed. Many respondents hoped for a special section in VSGM that would provide more detailed explanations about geomorphological maps. Respondent [R6], from an NGO, suggested that additional explanations or descriptions to clarify the images or terms would be very helpful. Similarly, respondent [R4], from BPBD, and respondent [R8], from an NGO, mentioned in the previous sub-chapter that they still need training sessions or practice time because many new terms require further clarification. This indicates a need for more detailed explanations of the terms on the map.

6.1.2. Affective dimension

Based on the thematic analysis of responses to the two open-ended questions (see Appendix 7 and Appendix 8), VSGM was found to evoke more positive than negative emotions in respondents (Table 6.2). This result likely explains why all respondents strongly agreed or agree that VSGM could enhance their ability as disaster communicators and bring benefits for wider stakeholder concerning in landslide risk reduction. However, despite the many positive emotions VSGM generates, there is one negative feeling felt by few respondents.

Table 6.2 Affective dimension, sub-dimensions and their items

Dimension	Sub-dimension	Items
Affective	Positive emotion	1. Meaningful 2. Self-efficacy 3. Worthwhile 4. Enjoyable
	Negative emotion	1. Worrisome

6.1.2.1. Positive emotions

Positive emotion refers to pleasant or desirable feelings that individuals experience, which typically enhance well-being and promote positive interactions. After their first experience using the VSGM, all respondents expressed a positive response. They reported that the map elicited feelings of meaningfulness, self-efficacy, worthwhileness, and enjoyment. A detailed explanation of how these four positive emotions emerged is provided below.

1) Meaningful

The first positive affect detected after respondents used VSGM was a sense of meaningfulness. This feeling indicates deep satisfaction and significance for the respondents. For instance, respondent [R4], from BPBD, said that the map's ability to display Earth's surface features so clearly was extraordinary. His statement showed he was very impressed and satisfied with the quality of the VSGM design. Similarly, respondent [R5], from BPBD, found VSGM very meaningful because he could immediately see its benefits after using the map.

"I rarely encounter a map that can display data and information as detailed and comprehensive as this one. As I mentioned earlier, this map provides me with a lot of information and new knowledge" said respondent [R5].

VSGM is also seen as a meaningful effort for disaster education advancement in Indonesia. Respondent [R1], from BPBD, mentioned, "*This map could potentially serve as an innovative tool for instructors like us to impart valuable education to the public*." Various learning media like VSGM are essential for disaster communicators to effectively convey important knowledge about the threats and risks surrounding communities. This makes VSGM particularly significant for respondents.

2) Self-efficacy

The second positive emotion respondents experienced after using VSGM was an increase in self-efficacy. Many felt more confident in completing their tasks as frontline workers responsible for landslide disaster risk reduction. For example, respondent [R4], from BPBD, stated, "With this map, the process of identifying landslide-prone areas has become much easier." respondent [R6], from an NGO, also highlighted the benefits of VSGM in identifying landslide-prone areas. Additionally, respondent [R2], from BPBD, noted that VSGM significantly aided their work in designing landslide mitigation strategies.

"This map makes things much easier for us, especially when we work in the disaster prevention and preparedness projects. For example, by Utilizing this map it will enhances my confidence in making EWS placement decisions" said respondent [R2].

For some respondents responsible for educating the public about the hazards and risks of landslides, VSGM simplifies their work. As respondent [R8], from an NGO, mentioned, "*It's much easier to explain using a medium like this geomorphological map compared to explaining directly without any visual aid*.". She though that the storytelling, illustrations and photos in VSGM make it accessible to non-geoscientists, giving it great potential as an engaging learning tool.

3) Worthwhile

All respondents agreed that VSGM is highly worthwhile and beneficial for the society. Its detailed scale provides crucial information, such as the proximity of houses to landslide sources and the number of homes and agricultural lands in hazard areas. This direct connection to community assets often makes residents more proactive in protecting them. Respondent [R3], from BPBD, stated, "*This VSGM is particularly important for those living in hazardous areas. If they can grasp the vital information on this geomorphological map, they will hopefully prioritize environmental safety when building houses or using land*."

Respondents also believe that VSGM will provide significant benefits not only for people living in landslide-hazardous areas but also for all stakeholders involved in disaster risk reduction. Respondent [R2], from BPBD, sees VSGM as a strategic tool that can facilitate discussions among government institutions on more effective and efficient risk reduction efforts. She said, "*This map (VSGM) facilitates discussions with other government institutions, such as Public Works and Environmental Departments, enabling us to collaborate on implementing* *effective risk reduction strategies*." Respondent [R7], from an NGO, added that VSGM will also greatly assist hamlet leaders and community members in designing mitigation efforts or DRR-based local policy in their areas.

4) Enjoyable

Respondents found VSGM to be an enjoyable medium to use. Despite occasionally encountering difficulties with unfamiliar scientific information, the unique design of VSGM made the learning process engaging. The comic section, in particular, was a highlight for many respondents. Respondent [R8], from an NGO, remarked, "*This comic is very interesting. The story and illustrations are good; I don't feel reluctant to read it*."

Respondent [R1], from BPBD, agreed with respondent [R8], noting that the comic made geomorphology maps seem accessible, even to those without a geoscience background. She stated, "*I find this comic really interesting because the visuals are quite illustrative and help explain the story, making it enjoyable to read*." The storyline, which reflects their work environment, combined with the appealing and informative illustrations, seemed to successfully engage respondents and spark their interest in the entire learning process using VSGM.

6.1.2.2. Negative emotions

While all respondents exhibited numerous positive emotions after using VSGM, some also expressed negative emotion. Negative emotion involves unpleasant or undesirable feelings that may lower well-being or trigger discomfort. This research found that some respondents expressed concern or worrisome about whether VSGM needs to be understood by all general public.

1) Worrisome

The primary concern detected was worrying about how the VSGM would be received by a broader public audience, specifically for the local people living in the landslide prone area. The complexity of the information presented in the VSGM was a significant reason for their concern, as they feared that many users, particularly local residents, might find it challenging to understand. Respondent [R7], from an NGO, was among those who voiced this apprehension.

"The complexity of the map may need to be simplified because I believe the local people or communities would still struggle to understand this extensive data. For example, the scarps symbols do not need to be differentiated into more than 10 meters and less than 10 meters. They can be merged instead" said respondent [R7]

Furthermore, respondent [R5], from BPBD, expressed concerns about conveying overly detailed information about landslide hazards and risks to local people. He believes that such detailed presentations can sometimes have unintended consequences.

"*If I share all this information to the local people, this map seems too complicated to understand. Besides, if they see this kind of information, I'm afraid it will scare them because we are also not sure how likely this area will be to landslide*." respondent [R5]

Respondent [R5]'s comments highlight the delicate balance between informing the public and avoiding causing undue alarm, emphasizing the need for careful communication strategies when sharing scientific data with non-expert audiences. Respondent [R1], from BPBD, also raised concerns regarding the accessibility of the VSGM for the broader community, particularly for elderly BPBD officers.

"*I agree that the local community needs to be introduced to this geomorphological map. Still, it might be easier to introduce it to young people, because maybe those in their 40s and above would find it difficult to understand such a map*." said respondent [R1].

Respondent [R7] pointed out that older individuals often have less familiarity with modern technology, including spatial products like maps. She worries that the complexity of interpreting these maps could pose a challenge for older adults, potentially limiting the effectiveness of the VSGM in reaching and educating all segments of the population.

6.1.3. Conative dimension

The conative dimension, which reflects respondents' intentions to take action after using VSGM, was explored through their willingness to share and use the map. The thematic analysis of their open-ended responses identifying at least three key points explaining to whom they intended to share VSGM (see Appendix 9 and Appendix 10). Furthermore, the analysis of their responses revealed at least three specific ways in which they planned to utilize the VSGM moving forward (see Appendix 11 and Appendix 12). Each item detailing respondents' willingness to share and use the map is presented in Table 6.3 and explained in the following subsections.

Table 6.3 Conative dimension, sub-dimensions and their items

Dimension	Sub-dimension	Items
Conative	Willingness to share	1. I would recommend this map to my workmate. 2. I would recommend this map to other institutions responsible for DRR. 3. I would recommend this map to DRR communities at regional to local level.
	Willingness to use	1. I would use this map as it is for my learning resources. 2. I would use this map as it is for discussion tools or teaching media. 3. I would only take some information from this map for discussion tool or teaching media.

6.1.3.1. Willingness to share

Based on the Likert scale results, all respondents confidently expressed a strong likelihood of sharing VSGM. During the subsequent deep interviews, there are at least three main groups respondents intended to share the VSGM with: their workmates, other institutions responsible for disaster risk reduction (DRR), and DRR communities at regional and local levels.

1) I would recommend this map to my workmates.

Respondents indicated that they would first share information about VSGM with workmates or colleagues within their own institutions. Respondent [R2], from BPBD, emphasized the crucial role of VSGM in disaster risk reduction efforts, stating that it should be disseminated to all BPBD offices across districts and cities. She expressed her willingness to assist in the dissemination process to BPBD offices throughout Indonesia.

"Oh, absolutely yes. Once this map is officially released, I will recommend it to my colleagues in the disaster management office, especially the BPBD offices across Central Java and throughout Indonesia because we are interconnected, working together in disaster management, and sharing information. We will demonstrate how important the geomorphological map is for disaster management or risk reduction" said respondent [R2].

Respondent [R8], who works for an NGO, shared a similar sentiment to respondent [R2], from BPBD. She emphasized that her colleagues in the NGO sector, particularly those involved in disaster education, should be informed about VSGM. During her interview, she stated *"I would highly recommend this map to my colleagues who also work as disaster educators. Because currently, we are working on a project to enhance the capacity of communities and government officials in dealing with landslide disasters in several areas.* Respondent [R8] added that her workmates should use this map because she believes it will significantly enhance their knowledge and understanding as disaster educators.

2) **I would recommend this map to other institutions responsible for DRR.**

Some respondents, especially those working at BPBD, mentioned that they would recommend VSGM to colleagues in other institutions involved in disaster risk reduction (DRR) efforts. For instance, respondent [R5], emphasized the importance of this map for his counterparts in Public Works and Public Housing, who often deal with constructing roads, bridges, or slope stabilization in landslide-prone areas. He believes that the detailed information in geomorphological maps, such as location, dimensions, characteristics, and causes of landslides, is crucial for planning infrastructure development. Respondent [R5] also suggested that VSGM should be recommended to governmental bodies responsible for spatial planning, because it can assist them in identifying area suitable for conservation or development.

"Furthermore, I intend to suggest this map to governmental bodies responsible for spatial planning, such as the Forest Agency and Development Planning Agency at Sub-National Level. I believe the comprehensive information provided by this map would offer them significant benefits, including aiding in the identification of areas for conservation and safe locations for development centers within villages" said respondent [R5].

3) **I would recommend this map to DRR communities at regional to local level.**

Most respondents expressed their willingness to share the VSGM with all disaster risk reduction (DRR) communities at both regional and local levels. These DRR communities are groups that assist the central government in implementing disaster risk reduction efforts on the ground or neighbourhood. Respondent [R4], from BPBD expressed his enthusiasm about sharing the VSGM with various DRR communities, such as the Disaster Response Team (TRC) at the district level and the

Disaster Risk Management Organization (OPRB) in each village. Respondent [R7], from an NGO also shared this willingness to disseminate the map among various DRR communities.

"Yes, I highly recommend it (the VSGM), especially for community-based disaster resilient facilitators. According to the information I have now from the readiness catalogue website, there are at least 7,000 facilitator groups, whether they are village-level facilitators from BNPB, prepared villages from the Ministry of Health, resilient coastal villages from the Ministry of Maritime Affairs, or whatever their name may be, as long as they are facilitators working at the community level. If they can understand this map, I think it would be very beneficial" said respondent [R7]

6.1.3.2. Willingness to use

Based on the Likert scale results, five out of eight respondents rated their likelihood of using the VSGM in the future as a 4, indicating they are likely to use it, while the remaining respondents gave the highest score of 5, meaning they are very likely to use it. Thematic analysis of their responses revealed that respondents are willing to use VSGM as a learning resource and discussion tool with their peers. However, those who scored 4 may only use select parts of the information in VSGM for specific reasons.

1) I would use this map as it is for my learning resources.

Many respondents expressed a strong willingness to use VSGM as a valuable learning resource, primarily due to the wealth of new information it offers. They see VSGM as an instrumental tool in deepening their understanding of geomorphology and enhancing their effectiveness as disaster communicators. The detailed data and comprehensive insights provided by the map are seen as crucial for improving their ability to analyze and communicate disaster risks. Respondent [R3], from BPBD, was particularly enthusiastic, emphasizing how the information contained within VSGM could significantly elevate their knowledge and skills, ultimately enabling them to better serve their communities in disaster risk reduction efforts.

"I will definitely use it for my own needs, especially to support my work in the field of disaster data and information management. This includes enhancing my insights and knowledge about the types of data needed to collect for landslide risk analysis. Then, it also adds to my understanding when I am asked to be a disaster educator in villages" said respondent [R3].

2) I would use this map as it is for discussion tools or teaching media.

Most respondents expressed a strong willingness in using VSGM as a discussion tool in the DRR forums. For instance, four respondents from BPBD are eager to incorporate VSGM into discussions with other government institutions. Similarly, respondent [R6], from an NGO, plans to use the VSGM in forums with other NGOs, private companies, or practitioners involved in disaster risk reduction.

"Of course I will definitely use it. Please, when the map is finalized, just give it to me immediately. Because just like I said earlier, this map can be an alternative medium when discussing landslide hazard potentials with my audience, perhaps with disaster practitioners or local government officials" said respondent [R6].

Respondents actively engaged in disaster education for DRR communities also expressed a strong interest in using VSGM as a teaching tool. Respondent [R1], from BPBD, emphasized that the map is particularly effective for community education, especially in training individuals to identify landslide-prone areas. She noted that VSGM's detailed information and visual aids make it an excellent resource for enhancing community understanding of landslide hazards and risks.

“I think I could include this map as part of our educational materials for our "Destana" or Desa Tangguh Bencana program. In "Destana," we teach how to map areas prone to landslides, and this map could be a valuable media for identifying landslide areas. This map contains more detailed and clearer symbols that can show area of active landslide and high risk of landslides.” said respondent [R1].

3) **I would only take some information from this map for discussion tool or teaching media.**

While all respondents generally expressed a strong interest in using VSGM, many indicated that they would not present the full map to local communities. They believe the current design of VSGM is too complex for the average local resident, suggesting that a simplified version is necessary for effective use in discussions or educational settings. Respondent [R7], from an NGO, highlighted that for local audiences, particularly villagers, the map’s information should be less detailed to be more accessible. The same opinion was also expressed by respondent [R4], from BPBD.

“I will use it when discussing with my colleagues, such as disaster response team and village officials. But if with the local people, it seems that this map is still too difficult to use because there are elderly people and children” said respondent [R4].

6.2. Discussion

This chapter examined users' perceptions of the VSGM as a tool for landslide risk communication, focusing on cognitive, affective, and conative dimensions. The eight respondents exhibited a consistent pattern in their Likert scale responses across all interview questions, suggesting a uniformity in perception that strengthens the reliability of the qualitative data. The cognitive dimension was explored by assessing participants' perceived usefulness and ease of use of the

VSGM. The affective dimension was analysed by exploring the range of emotions—both positive and negative—those participants experienced after using the VSGM. Finally, the conative dimension was investigated by evaluating participants' willingness to use and share the VSGM.

The thematic analysis revealed a dual nature in respondents' experiences with the VSGM. While some respondents found the map challenging to master, they remained highly enthusiastic about using and sharing it. This enthusiasm is believed to be driven by their perceived usefulness and the positive emotions they feel thereby increasing their intended use. Although respondents acknowledged that the VSGM is not easy to master on the first attempt, this did not pose a significant issue, as they were eager to deepen their understanding through expert-led training sessions. They emphasized that mastering the VSGM required several practice sessions before they felt confident using it independently. The respondents' willingness to engage in additional practice sessions reflects their commitment to fully grasping and utilizing the VSGM's capabilities. This eagerness to invest time in learning suggests that users recognize the map's potential value and are motivated to overcome initial challenges to benefit from its insights.

6.2.1. VSGM as an informative, engaging and adoptable tool

Despite the challenges, all respondents found the VSGM design to be informative. The use of 3D visualizations and photographs on the geomorphological map effectively conveyed realistic representations of topographic and geomorphic features, making it easier for users to grasp the geographical context of the mapping area (Fraile-Jurado et al., 2019). The comic storytelling that introduces the concept of a geomorphological map—explaining its importance and how to use it—proved to be an effective approach. Respondents likened the comic to a prologue that sets the stage before engaging with the map itself. This finding provides valuable empirical evidence of how narrative storytelling can enhance public understanding (Shanahan et al., 2018) particularly to the role of geomorphological map in landslide risk reduction. Additionally, the instruction sheet played a crucial role by guiding users through the map, preventing them from getting lost and helping them more easily understand its meaning and purpose (Denil, 2016).

The VSGM design successfully generates many positive emotions among users. Respondents felt that the information presented in the map was entirely new to them, making the VSGM feel particularly meaningful. They also experienced an increase in self-efficacy after using the VSGM. These positive emotions likely stem from the map's ability to meet their needs as disaster communicators (Gegenfurtner et al., 2014). The perceived value and benefits of the VSGM for the wider community further reinforce its worth as a communication medium. Furthermore, respondents found the VSGM to be both interesting and enjoyable. The use of storytelling through illustrated comics effectively evoked emotions and enhanced user engagement in text-based communication (Z. Wang et al., 2022). Moreover, the inclusion of instructional sheets contributed to a sense of enjoyment by creating a smooth flow that helped users easily navigate and achieve their map-related goals (Sherry, 2004).

All respondents expressed strong enthusiasm for using and sharing the VSGM in the future. They believed it could serve as an effective learning and discussion tool for themselves and others working in disaster management. Many were eager to introduce the VSGM to colleagues, both within their own institutions and across different organizations. Despite finding the VSGM challenging to master, their high willingness to use and share it appears to be driven by its perceived usefulness and the positive emotions it evokes. This aligns with findings from (Lee et al., 2005; Saadé, 2007), who also observed that perceived ease of use is not always significantly related to the intention to use a learning tool. Conversely, numerous studies have demonstrated a strong positive correlation between intention to use and perceived usefulness, as well as positive emotions (Collazo et al., 2014).

6.2.2. The needs for prioritizing perceived usefulness and positive emotion

The findings from this chapter have several important implications for the design and implementation of visual storytelling-based geomorphological maps in disaster risk communication. First, the strong enthusiasm among respondents to use and share the VSGM, despite the challenges they faced in mastering it, suggests that perceived usefulness and positive emotional engagement are key drivers in the adoption of complex educational tools. This highlights the importance of prioritizing these elements in the design process, particularly when targeting professionals or frontline communities in disaster management who may need to invest time in learning how to use new tools effectively (Bagdi & Bulsara, 2023; Wong et al., 2023).

Many studies have shown that perceived usefulness is one of the key factors in the adoption and use of communication medium (Hazel & Kang, 2018; Kim et al., 2011). This perception serves as a powerful motivator, driving individuals to engage with a medium (Amoako-Gyampah, 2007). This likely explains the respondents' strong enthusiasm for using and sharing the VSGM, as they recognize its significant benefits in landslide risk reduction countermeasures. After using VSGM, respondents recognized that, detailed geomorphological maps offer critical information—such as location, dimensions, characteristics, causative factors, and potential landslide areas—essential for predicting impacts and designing effective mitigation measures. This recognition likely fuels their strong willingness to embracing and disseminating the VSGM as a vital tool in disaster risk reduction.

This chapter 's findings contribute to the broader discourse on the role of perceived ease of use versus perceived usefulness in the adoption of disaster risk communication media. While ease of use remains an important factor, this research reinforces the idea that professionals are willing to overcome usability challenges if the tool provides significant value. As emphasized by Griffin et al., (2017), understanding how maps can be meaningful and insightful for users is more crucial than ever, as this connection can inspire them to use the maps, even when effort is required. Therefore, map makers should focus on maximizing the perceived benefits of such tools while providing adequate training resources to mitigate usability issues.

6.2.3. Insights into the emergence of negative emotion

Despite many positive perceptions emerged, some respondents expressed their worrisome after using the VSGM. These concerns were especially voiced by respondents who also have responsibility to educate local people or high school students about potential landslide hazards and disaster risk reduction. They questioned whether the detailed information on the derivative geomorphological map could effectively serve as a communication tool for these group of communities. Besides due to the low education levels and limited map-reading abilities, there was also a concern that the detailed landslide information might cause unnecessary alarm for those living in at-risk areas. Meanwhile, for high school students, the information presented in the VSGM may be overly dense and challenging to comprehend.

Although respondents recognized that the VSGM was designed for disaster communicators rather than laypeople or high school students, they expected about its potential use as an educational tool for these audiences. This feedback underscores the VSGM's promise as a mass communication medium suitable for broader community engagement. These results once again demonstrate the power of storytelling as a reliable communication technique for conveying scientific findings to the public (Dahlstrom, 2014; Roth, 2021b). As a result, there is considerable opportunity for future research aimed at adapting the VSGM to be more accessible and effective for diverse groups, such as laypeople, high school students, and other segments of society. This adaptation could significantly enhance the VSGM's impact and usability across a wider demographic.

Chapter 7 - Results: Future Development of The VSGM Design

7.1. General overview of the SWOT results

The SWOT analysis of the Visual Story-based Geomorphological Map (VSGM) reveals valuable insights for its future development as a tool for landslide risk communication in Indonesia and other vulnerable regions. By considering the strengths, opportunities, weaknesses, and threats (Figure 7.1), a clear path for enhancing the VSGM and addressing challenges for broader adoption can be made. These insights will help guide strategic improvements to ensure the VSGM meets the needs of diverse user groups while remaining effective and accessible.

Strengths

1. Co-production: VSGM is a collaboration product between multidisciplinary professionals and users.
2. Map usability: Most elements of the VSGM design have been found to be user-friendly for completing the assigned tasks.
3. Perceived usefulness: VSGM design helps users understand the role of geomorphological maps in reducing landslide risk.
4. Perceived easy to use: VSGM design has shown that geomorphological maps are possible to understand and use by non-expert.
5. Positive affect: VSGM design has been able to evoke many positive emotions in map users.
6. Willingness to share: VSGM has great potential to be disseminated to various groups in society.
7. Willingness to use: VSGM has great potential for use in a variety of applications.

Weakness

1. Certain elements of VSGM are challenging for users to understand.
2. Need more detailed explanations about the terms on the map.
3. Several training sessions are needed for users to fully master all the information presented on the map.
4. The VSGM design occasionally elicits a negative emotion from map users.

Opportunities

1. Many domestic and international stakeholders are involved in landslide risk reduction.
2. The accessibility of high-resolution spatial data is steadily increasing
3. Significant advancements in GIS technology and graphic design are rapidly emerging.

Threats

1. Limitation of static and paper-based maps.
2. The necessity for substantial funding and human resources to cover all landslide-high risk areas in Indonesia.

Figure 7.1 SWOT analysis of the VSGM design

7.1.1. Strength identification

The VSGM offers at least seven notable strengths as an innovative medium for landslide risk communication. First, it is a product of collaboration among various experts and map users, ensuring that diverse perspectives and valuable input have been incorporated into its design to meet user needs. Second, usability evaluations have demonstrated that the VSGM features a user-friendly design that facilitates users in completing tasks and understanding the map's objectives. The remaining strengths, from the third to the seventh, highlight the VSGM's ability to generate positive user perceptions, including perceived usefulness, ease of use, the elicitation of positive emotions, and a willingness to share and use the map. These strengths underscore the VSGM's readiness to be adopted as an effective landslide risk communication tool.

7.1.2. Weakness identification

Despite its many strengths, the current VSGM design has several weaknesses. First, usability evaluations reveal that certain elements of the VSGM remain difficult for users to understand, preventing them from completing tasks independently without expert assistance. Second and third, an analysis of user's perceptions shows that some users often lack confidence in using the VSGM without expert guidance, expressing a need for more detailed explanations of map terms and additional training sessions to fully master the map. Lastly, some users have expressed concerns and a desire for the VSGM to be adapted for use as a communication tool for local communities and high school students.

7.1.3. Opportunity identification

Indonesia, as a country with extensive landslide risk areas, presents significant opportunities for the expansion of VSGM. The need for landslide risk communication tools is immense, particularly as many disaster communicators do not have a non-geoscience background. This creates an ideal environment for the dissemination of VSGM to a diverse range of societal groups, bridging the gap between scientific information and practical understanding. Additionally, the rapid advancement in GIS technology and graphic design, coupled with the increasing availability of high-resolution spatial data, presents an opportunity to improve VSGM's accuracy and visual quality. These technological advancements could also help tailor the VSGM to a wider variety of regions, further enhancing its relevance and impact.

7.1.4. Threat identification

The limitations posed by static, paper-based maps present a significant threat to the scalability and efficacy of VSGM in the future. While paper maps are widely accessible, they restrict the dynamic interaction that digital platforms can offer. This limits the map's adaptability and the ability to update information in real time, which is critical in the context of landslide risk communication. Furthermore, expanding the VSGM to cover all landslide-prone areas in Indonesia would require substantial funding and human resources, a significant challenge given the scale of the task. Securing consistent financial and institutional support is essential to ensuring the widespread adoption and sustainability of the VSGM as a reliable tool.

7.2. Discussion

This chapter outlines strategies for the future development of the VSGM as an effective tool for landslide risk communication, using a SWOT analysis. Based on the evaluation of strengths, weaknesses, opportunities, and threats, three main strategies are proposed: leveraging strengths to capitalize on opportunities, addressing weaknesses to minimize risks, and reducing the impact of potential threats to ensure long-term efficacy. A framework of these strategies including with the actions is presented in Figure 7.2 and further elaborated in the subsequent sub-chapters.

7.2.1. Leveraging strengths to capitalize on opportunities

The first proposed action in leveraging strengths to capitalize opportunities is by expanding the targeted users of the VSGM. Given Indonesia's extensive number of disaster communicators without a background in geomorphology or geosciences, the user-friendly design of the VSGM presents an opportunity to be introduced to a wider audience. For example, in Indonesia case, government institutions responsible for communicating disaster risk to the public are not limited to the National Disaster Management Agency (BNPB). Other key agencies, such as the Ministry of Forestry, the Ministry of Agriculture, and the National Development Planning Agency, also play significant roles in disaster risk communication. Therefore, future development design for the VSGM could be directed toward these community groups.

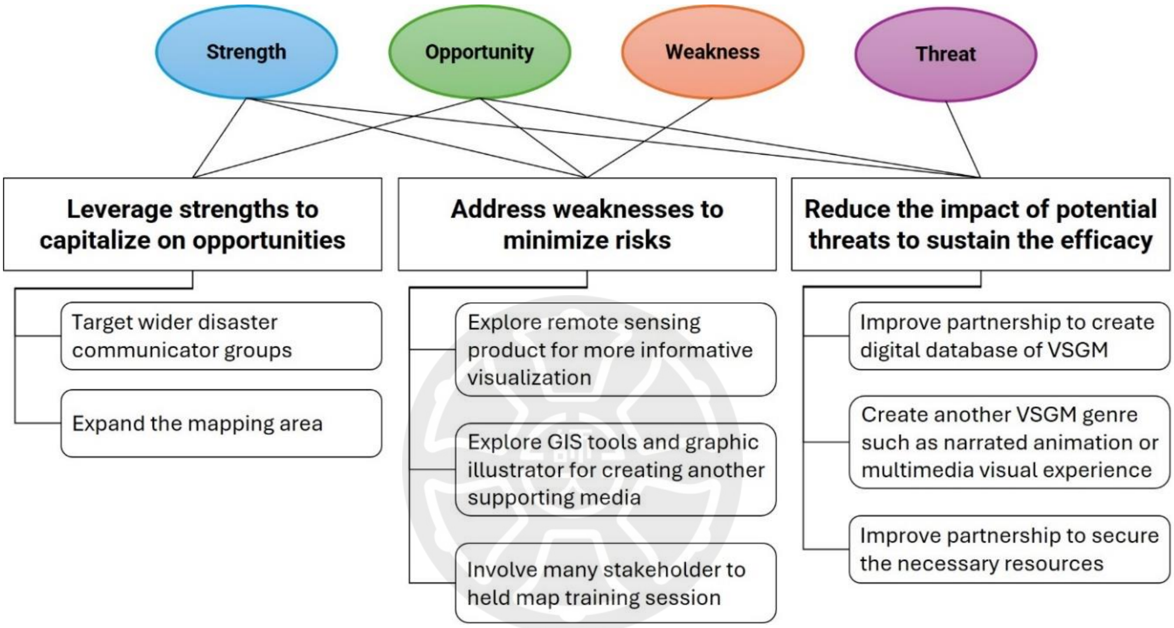


Figure 7.2 Framework for strategies in the future development of the VSGM

The second proposed action involves expanding the area of geomorphological mapping represented in the VSGM. Although high-resolution data sources, such as LiDAR, UAV, and satellite-based systems, which are essential for creating detailed geomorphological maps, do not yet cover all of Indonesia, there is increasing enthusiasm among geoscientists to adopt this technology (Samodra et al., 2020; Vernimmen et al., 2019; Widyaningrum & Gorte, 2017). This remote sensing research advancement creates a significant opportunity for the establishment of detailed geomorphological maps and the broader implementation of the VSGM across larger regions.

7.2.2. Addressing weaknesses to minimize risks

The first proposed action to address weaknesses and minimize risks is to explore remote-sensing products for more informative geo-visualization. While the VSGM has demonstrated overall good usability, certain elements remain challenging for users to understand. One significant difficulty lies in the representation of rotational and translational landslide types, which many users struggle to grasp. This issue appears to be linked to users limited prior knowledge of landslides, making it difficult for them to interpret information presented through sketches alone. A potential solution is to adopt alternative visualization techniques, such as incorporating high-resolution, real-world images captured by UAVs. When enhanced with graphic design, these images could offer more intuitive and accessible visual representations. Research supports this approach, with studies indicating that real-world photography can improve learning outcomes by providing visual context, engaging users, and deepening their understanding of geographic concepts (Fraile-Jurado et al., 2019; Henderson & Rickard, 1972).

The second proposed action to address this VSGM weakness is exploring GIS tools and graphic illustration to create another supporting media on the VSGM. One of the concerns from map users is about the needs of more detailed information about geomorphology and landslide knowledge. To accommodate the diverse needs of different map users, expanding the range of supporting media will allow the VSGM to reach a broader audience in the future. One potential solution is the development of a booklet that provides more in-depth explanations of scientific terminology and geomorphological map content. For users who are keen to gain a deeper understanding of geomorphology, the current VSGM design may not fully meet their expectations. Therefore, producing supplementary materials like a detailed booklet is a viable option for future development. This booklet could offer comprehensive explanations of maps, landforms, and how geomorphological maps can be applied to landslide risk reduction, without overloading the map with excessive information.

Developing another supporting material, such as simplified versions of geomorphological maps, is also essential to address the concerns of landslide communicators who experience negative emotions when attempting to use the VSGM with local residents or high school students. These communicators recognize the importance of introducing geomorphological features to raise awareness of disaster risks in their communities, yet they worry that the detailed information in the VSGM may be too complex for these groups to grasp. The simplified geomorphological map would not replace the original VSGM but would serve as a complementary tool, providing more accessible content. As noted by Driedger et al., (2024), creating simplified maps alongside more detailed hazard maps can broaden their applicability and make them more useful to a wider range of users.

The final action to address the weaknesses of the VSGM is to involve multiple stakeholders in organizing training sessions for the target users. Many respondents expressed the need for multiple training sessions with experts to gain confidence in using the VSGM effectively. They felt unsure about navigating the tool without expert guidance after just one attempt. Given that the VSGM introduces new and complex information, these training sessions are crucial to ensuring users can fully understand and utilize the map. The importance of educational programs or training session in the successful dissemination and application of disaster communication tools is also highlighted in the Sendai Framework for Disaster Risk Reduction (ISDR-ICL, 2015). Offering training sessions to non-expert users can help overcome the challenges they face and ensure that they can use the VSGM correctly.

7.2.3. Reducing potential threats to sustain the efficacy

Two significant external threats must be addressed to ensure the long-term sustainability of VSGM development: the limitations of static, paper-based maps and the need for substantial funding and human resources to create maps covering all high-risk landslide areas in Indonesia. Static maps present several weaknesses, such as susceptibility to physical damage, higher costs for dissemination, and limited capacity to adapt to dynamic changes in information. Therefore, a key direction for the future of VSGM should involve transitioning from static to digital format. By creating digital database of VSGM, users can download and print themselves, reducing concerns about physical damage and making dissemination more cost-effective and efficient.

Further development could involve creating different genre of VSGM such as an interactive, web-based map, which would offer dynamic functionalities such as real-time data integration, user interactivity, and scenario-based simulations. These features are critical for modern risk communication strategies, offering flexibility and responsiveness that static maps cannot match (Keon et al., 2014; Yang et al., 2023). However, it is important to note that the interactive web-based map is not intended to replace static maps but rather to complement them. Since each map format has its own strengths and weaknesses (Nossum, 2012), the coexistence of both is expected to enhance the overall effectiveness of the VSGM as a communication tool with the wider users.

Finally, future development must address the challenge of securing sufficient funding and resources for the widespread deployment of VSGM. Given the scale of Indonesia's landslide-prone areas, a comprehensive rollout of VSGM requires significant investment in both human resources and technology. Previous studies on the implementation of large-scale communication tools have demonstrated that long-term success depends on consistent funding, government support, and cross-sector collaboration (Howes et al., 2015). By building strong partnerships with government agencies, research institutions, educational institution and international organizations, the VSGM initiative can secure the resources needed for sustained growth and impact.

Chapter 8 - Discussion: Toward A New Approach to Effective Landslide Risk Communication

8.1. Holistic view from the research findings

This chapter synthesizes the key insights gathered from all stages of the research, aligning them with the primary objectives of the study. This section bridges the gap between the design, usability, and user perception of the Visual Story-based Geomorphological Map (VSGM), highlighting how each aspect contributes to its effectiveness as a tool for landslide risk communication in Indonesia. By integrating the results from co-production mapping, usability testing, and user perception evaluation, this section provides a comprehensive understanding of the VSGM's ability in promoting detailed geomorphological maps for landslide risk communication tools to non-expert users. In the finale stage, the SWOT analysis also offers critical reflections on the strengths and areas for improvement, guiding future development of the VSGM for broader application in disaster risk communication and wider map user groups

8.1.1. The importance of co-production in VSGM design

Co-production plays a pivotal role in the design process of the Visual Story-based Geomorphological Map (VSGM), serving multiple key functions that enhance both the quality and effectiveness of the final product. First and foremost, co-production ensures that the map's objectives are closely aligned with the needs and expectations of its intended users. By actively involving users in the design process, it becomes possible to validate that the information being communicated through the VSGM addresses their real-world concerns, such as understanding landslide risks and making informed decisions. This user involvement approach shifts the focus from merely creating a technically sound product to one that is user-cantered, ensuring the map is not only functional but also accessible and engaging for its target audience (Roth et al., 2015; S. Shen et al., 2023). The validation of user needs can also be supported by insights from other experts involved in the process (Driedger et al., 2024). With their extensive experience in the field of disaster risk reduction, these experts frequently interact with landslide risk communicators, the primary target users of the map. As a result, they have a deep understanding of the current challenges and needs faced by map users.

Furthermore, co-production facilitates the collection of valuable feedback from a diverse range of stakeholders, including users and multidisciplinary experts. This collaborative process integrates various perspectives and areas of expertise, resulting in a more holistic understanding of how the map can be refined to improve its usability (Vollstedt et al., 2021). Experts from fields such as cartography, disaster management, geography education, learning media, and design illustration contribute insights that ensure the VSGM maintains scientific rigor while remaining an effective tool for risk communication. They also provide critical input on communication and educational concepts, which are often overlooked by geomorphologists. Meanwhile, users, with their practical experience using risk communication tools, offer feedback on how to make the map more intuitive and impactful. They help identify potential barriers that could hinder its use. This iterative feedback process fosters continuous improvement, allowing the map to evolve and better serve both its users (Luke et al., 2018) and the broader goal of promoting geomorphological maps as effective tools for landslide risk communication.

8.1.2. VSGM as an effective landslide risk communication tool

The analysis encompassing the design process, evaluation, and future development indicates that the VSGM is a highly promising and innovative approach to landslide risk communication. There are five key reasons supporting the effectiveness of VSGM as a communication tool (Figure 8.1). Firstly, the VSGM results from collaboration among multidisciplinary professionals and map users. This collaborative approach ensures that the design has been rigorously tested by various experts and that the map's objectives align well with user needs.

Second, the usability evaluation confirms the VSGM's user-friendly design, demonstrating that most respondents could easily navigate the map and clearly understand its intended purpose. This usability result reflects that VSGM design effectively make complex geomorphological information accessible to non-expert users. Usability evaluation is also commonly used as a parameter to assess the level of effectiveness of maps as a learning medium, where good usability results will indicate that the map has an effective design (Behrens et al., 2015; A. C. Robinson et al., 2020). Additionally, the findings highlight the effectiveness of the co-production, which involved collaboration with stakeholders during the VSGM design process. By incorporating user and professional input allowed the map design to minimize obstacles during the map reading, thereby maintaining its usability (Roth et al., 2015, 2017).

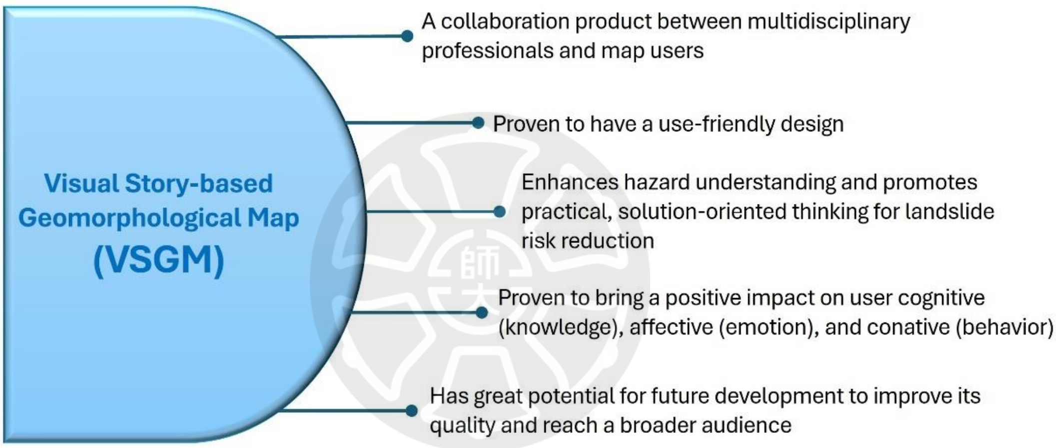


Figure 8.1 Five key reasons supporting the effectiveness of VSGM as a landslide risk communication tool.

Third, the VSGM's combination of detailed geomorphological information with a user-friendly design enables users to reach higher cognitive learning, particularly in application level. When users can complete VSGM’s tasks, they not only gain an understanding of landslide hazards but also engage in practical, problem-solving activities aimed at reducing landslide risk. They could use the map effectively to identify high-risk zones, predict the potential scale of impacts, and determine appropriate mitigation efforts and their locations. This demonstrates that the VSGM design advances landslide risk communication by addressing practical needs beyond basic information comprehension.

Fourth, the user-friendly design of the VSGM that promotes higher cognitive learning enable to shape users' positive perceptions including their cognitive, affective and conative toward geomorphological maps as tools for landslide risk reduction. The first positive perception highlighted by users cognitive is the high perceived usefulness of the VSGM. This encouraging outcome is largely attributed to the VSGM's design, which successfully guided users to engage with the map and grasp its core messages—emphasizing the benefits of geomorphological maps in mitigating landslide risks. The study found that high perceived usefulness often indicates the actual effectiveness of the communication process (Dillard et al., 2007). In this context, the benefits experienced by respondents during the evaluation can represent the real advantages they would gain when using the VSGM in the future.

Another key positive perception expressed by users is the emergence of positive emotions associated with the VSGM. Users perceive the VSGM not only as an informative tool for understanding and communicating landslide risks but also as a medium that is meaningful, engaging, and enjoyable to use. This positive experience fosters a sense of self-efficacy, enhancing users' confidence in their ability to act as a good disaster communicator. It empowers them to convey complex geomorphological information with greater clarity and impact, fostering a sense of competence in dealing with risk communication. As a result, users are more inclined to use and share the VSGM, recognizing its potential to enhance risk communication across broader audiences. This aligns with research showing that emotionally engaging tools not only improve user engagement but also promote a deeper commitment to sharing knowledge. The influence of VSGM design quality on user perception toward the map is illustrated in Figure 8.2.

The positive perceptions from users' experience with the VSGM strongly indicate its high quality as a risk communication instrument. This aligns with the findings of Alkhawaja et al., (2022), who demonstrated a significant positive relationship between the quality of learning media systems and students' perceived usefulness and intention to use. Similarly, Mohammadi, (2015) found that perceived usefulness can mediate the relationship between system quality and users' intentions, suggesting that a system perceived as useful is more likely to be accepted and utilized by its users. This relationship is further supported by multiple studies showing that successful communication efforts often lead to positive emotional responses from users, which in turn influence their behaviour (Hazel & Kang, 2018)

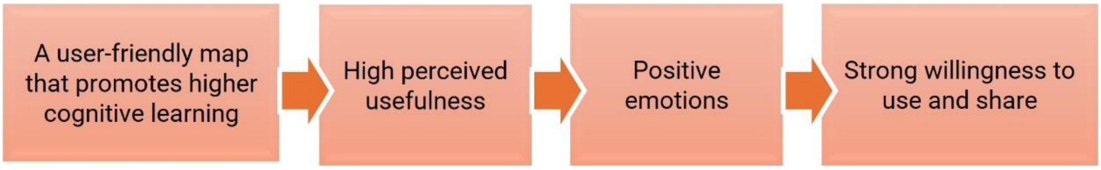


Figure 8.2 The flow illustrates how cartographic design quality affects users' perception of the VSGM.

Finally, while the evaluation results highlight the VSGM's potential as an effective tool for landslide risk communication, there are still areas for improvement. The SWOT analysis reveals certain shortcomings, such as sections of the map that users find difficult to understand, the need for more detailed information, and a desire for training sessions and adaptations for specific social groups. Additionally, the current paper-printed format of the static VSGM poses challenges, including the risk of damage and high distribution costs. Nevertheless, promising opportunities exist, such as the involvement of numerous domestic and international stakeholders in landslide risk reduction, improved accessibility to high-resolution spatial data, and advancements in GIS technology and graphic design. These factors suggest that the identified weaknesses and threats can be potentially addressed in the future. Therefore, future research dedicated to overcoming these challenges will be essential for enhancing VSGM’s impact and effectiveness.

8.1.3. The role of storytelling in determining the effectiveness of geomorphological map as landslide risk communication.

The integration of storytelling approach has proven highly effective in making geomorphological map a user-friendly tool for communicating landslide risk to non-expert users (Figure 8.3). Users reported minimal difficulties when interacting with the geomorphological information, suggesting that the map successfully balances complexity and accessibility. Comic as the first visual story-based supporting media emphasising continuity, voice, metaphor and mood aspect was found to be instrumental in setting the context before users engaged with the geomorphological map. The stories and illustrations provided a clear and accessible introduction to the concept of geomorphological mapping and the key topics covered, making the technical information more approachable. Furthermore, the inclusion of relatable characters and engaging storylines had a notable emotional impact, increasing user interest and involvement with the map (Gustafson et al., 2020). This demonstrates that visual storytelling elements not only enhance the cognitive understanding of the map but also have a persuasive effect, fostering greater user engagement and facilitating a deeper connection to the information presented (T. Huang & Grant, 2020; Kelly et al., 2014) .

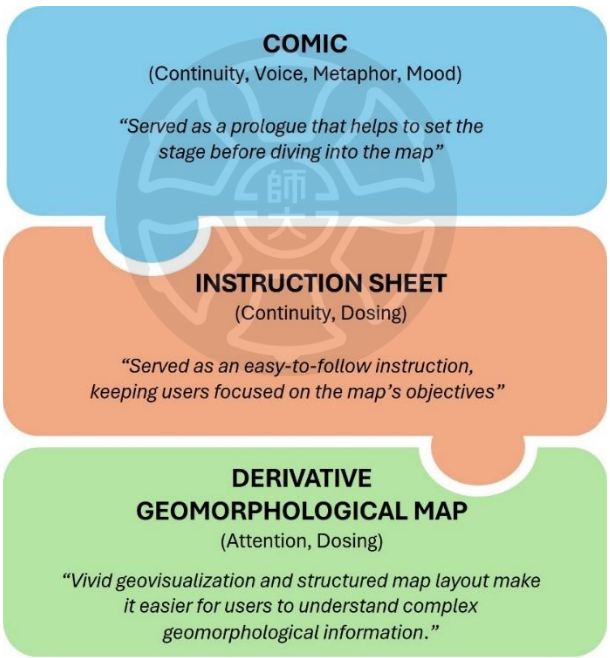


Figure 8.3 The role of storytelling tropes in shaping the function of each VSGM element.

Instruction sheets, as the second visual story-based supporting media emphasizing continuity and dosing aspect, were also found to play a vital role in guiding users through the geomorphological map and helping them grasp the map's main purpose. These instruction sheets served as a navigational aid, ensuring that users did not lose direction or focus as they explored the map. By providing clear and structured guidance, the instruction sheets helped users stay aligned with the map's intended goals and objectives. This function is particularly important in light of Denil's (2016) observation that individuals often interpret maps in different ways based on their personal experiences and knowledge. Without proper guidance, users may construct divergent narratives or miss the intended message of the map. The instruction sheets thus act as a crucial tool for harmonizing the user's understanding with the map maker's intent, ensuring that users arrive at the same final conclusions and grasp the key insights the map seeks to convey. This alignment not only enhances the map's usability but also strengthens its communicative power, making the VSGM a more effective tool for landslide risk communication. The role of instruction sheets in unifying user interpretations highlights their importance in preventing miscommunication and ensuring that the map achieves its intended impact.

The vivid geovisualization and structured layout of the derivative geomorphological map simplify complex scientific data and clearly present its four objectives. The vivid geovisualization using advanced remote-sensing techniques like LiDAR and UAV imagery enhance the depiction of the earth's surface, enabling users to understand the environmental conditions of the mapped area even without visiting it. The structured layout helps maintain user focus, making the map more accessible and informative. Together, these elements enable users to grasp the map's purpose, which goes beyond understanding hazard and risk concepts to actively engaging in practical disaster risk reduction measures, fulfilling its role as a tool for effective risk communication (Alcántara-Ayala, 2018; Dransch et al., 2010).

8.2. Contribution of the research

8.2.1. New strategies on popularizing geomorphological map

Although geomorphological maps are highly valued among geoscientists for their role in natural hazard and risk management, they are still largely underutilized by the public and those outside the geosciences. Compared to more familiar geological and slope maps, geomorphological maps offer detailed insights into landforms and the natural and human processes shaping them, which can be instrumental in understanding hazards like landslides (Smith et al., 2011). However, their complexity often limits their use to professionals in geoscience and geoengineering fields, as non-expert audiences find them challenging to interpret (Griffiths & Abraham, 2008a).

This research introduces a novel approach to enhancing the use of large-scale geomorphological maps for better landslide risk communication among non-experts. By integrating storytelling-based media, such as comics and instructional sheets, this study moves beyond the traditional practice of oversimplifying maps into landslide zoning maps, which often sacrifices many critical information such as in earlier research (Alcántara-Ayala et al., 2018; Karnawati, Fathani, Wilopo, & Andayani, 2018). Instead, the proposed approach facilitates the communication of more detailed scientific data, enabling non-experts to gain a deeper understanding of hazards and risks. This enriched information not only enhances local spatial knowledge but also motivates them to engage in site-specific mitigation planning, thereby contributing to more effective DRR efforts. Furthermore, this innovative approach offers significant potential for adoption by scientists aiming to make their specialized maps accessible and meaningful for broader, non-expert audiences.

This research also recommends two essential strategies to amplify the quality and impact of VSGM. First, applying a co-production approach ensures that the VSGM meets user needs while maintaining a user-friendly design. In addition to testing with map users, involving diverse professionals—including cartographers, disaster management experts, educators, learning media specialists, and illustrators—offers valuable insights often missed by geomorphologists. The involvement of map users and experienced professionals in the map-making process is crucial for minimizing obstacles during use, thereby enhancing the map's overall usability. Hengl & Husnjak, (2006) also emphasize the importance of end-user involvement, noting that the low popularity of soil maps among decision-makers in Croatia is attributed to poor map usability, which stems from insufficient end-user engagement in the map-making process.

Second, this research emphasizes using visual storytelling to strengthen users' perceived usefulness and positive emotions over prioritizing ease of use. Findings reveal that when users recognize geomorphological maps as valuable in landslide risk reduction and see their relevance both for themselves as disaster communicators and for the wider community, they become motivated to use and share these maps in the future. When a communication tool positively influences users' behaviour—specifically their willingness to use and share—it becomes an indicator of successful communication (Mohammadi, 2015). Typically, when a medium effectively engages users' conative aspects, they are more inclined to invest time and effort in mastering it, as observed in this study. Despite many respondents finding the VSGM challenging to master at the first time, they expressed a willingness to learn or even undergo training to become proficient in its use.

8.2.2. Advancing landslide risk communication with innovative approaches

This study makes a significant contribution to the field of risk communication by advocating for the development of maps that go beyond the traditional role of information dissemination. It emphasizes the importance of designing risk communication tools that actively empower users to address real-world challenges, thereby ensuring their practical utility and long-term relevance. The Visual Story-based Geomorphological Map (VSGM) exemplifies this innovative approach by integrating both understanding and application-oriented functions. Beyond enhancing users' understanding of hazards and risks, the VSGM facilitates practical decision-making by assisting users in identifying at-risk areas and designing site-specific disaster risk reduction (DRR) strategies. By aligning the map's functionality with user needs, the VSGM fosters a high level of perceived usefulness and elicits positive emotional responses, ultimately cultivating a strong willingness to adopt and utilize the tool.

VSGM design enables scientists to showcase the practical applications of geomorphological maps in landslide risk reduction, such as identifying risk-prone areas, estimating potential impacts of landslide events, and facilitating the practical design of mitigation strategies. While many existing landslide-related maps primarily aim to enhance users' understanding of landslide phenomena by presenting scientific information only such as those presented by (Karnawati, Fathani, Wilopo, & Maarif, 2018; Setiawan et al., 2021) , the VSGM design goes further by equipping users with tools to apply this knowledge in real-world contexts.

When users recognize the practical benefits of geomorphological maps for disaster risk reduction, it can generate positive emotions that motivate future use. User-testing evaluations demonstrate that the VSGM is perceived as a meaningful, useful, and enjoyable communication medium, while also enhancing users' self-efficacy as disaster communicators. This increases their willingness to use the VSGM in the future, with some even expressing interest in utilizing it as a platform for discussing landslide risk issues with other stakeholders. These findings highlight the VSGM's ability to persuade users to actively engage in landslide risk reduction efforts and underscore its effectiveness as a risk communication tool such as stated by Alcántara-Ayala, (2018) and Bourrier & Biede, (2018) .

8.2.3. Empirical evaluation of map usability and user perception

This research contributes to empirical studies within the field of cartography, especially by expanding the understanding of how visual storytelling can enhance geomorphological map communication. Unlike studies focused solely on map design (Rodgers et al., 2020; Vollstedt et al., 2021), this research uniquely integrates usability assessments and user perception, offering a deeper, evidence-based insight into the practical effectiveness of visual storytelling in maps. By systematically evaluating the Visual Storytelling Geomorphological Map (VSGM) design, this research examines how specific storytelling elements impact users' comprehension and engagement with geomorphological information. Such analyses enable us to measure not only the immediate usability but also the long-term communicative impact of these maps on users who may not have a geoscience background.

In exploring how users respond to these visual storytelling features, this study provides critical insights that can guide the development of more intuitive and accessible map designs. These findings lay a foundational framework for future studies by highlighting effective design strategies that resonate with targeted audiences, such as disaster communicators and public users, who require clear, actionable insights into landslide risk reductions efforts. Through this empirical approach, the research identifies ways to refine current cartographic practices and pioneer new design techniques that enhance the accessibility, informativeness, and impact of scientific maps. Ultimately, this contribution supports the evolution of maps as dynamic, cross-disciplinary communication tools capable of conveying complex scientific concepts in an accessible, engaging format for a wide array of users.

8.2.4. Contribution to interdisciplinary knowledge

This work bridges the gap between geomorphology, cartography, communication studies, education and disaster management. By intersecting these disciplines, this research enriched academic discourse and opened avenues for interdisciplinary collaboration. The co-production process of the Visual Storytelling Geomorphological Map (VSGM) exemplifies the need for interdisciplinary knowledge from the initial stages of development. This research demonstrates that creating a user-friendly, informative map requires more than just geomorphological and cartographic expertise. By involving disaster management experts, geography educators, learning media specialist, and design illustrators, the design process becomes enriched by diverse perspectives.

This research also leverages interdisciplinary knowledge in the evaluation phase by assessing the VSGM's effectiveness beyond usability metrics. While cartographic quality standards are important, this research acknowledges that a tool designed to communicate landslide risks must also be evaluated based on its psychological and perceptual impact on users such as stated by Dransch et al., (2010) and Griffin et al., (2017). By adopting the Cognitive-Affective-Conative (CAC) model, this work introduces elements of psychology into the evaluation process, measuring how users cognitively engage with the map, emotionally respond to its content, and are motivated to act. This interdisciplinary evaluation method reveals the VSGM's impact on users' perceptions, not only as a map but as a potential tool for landslide risk mitigation. Qualitative insights drawn from the CAC model highlight how users perceive the map's role in raising awareness and understanding of landslide risks, influencing future behaviour in using the map. This unique blend of cartographic, psychological, and disaster management perspectives underlines the map's utility as a comprehensive risk communication tool, advancing how interdisciplinary methodologies can assess map-based tools for real-world applications.

8.3. Acknowledgment of Limitations

While this study offers positive findings and valuable contributions to both academia and society, it is essential to recognize certain limitations, especially regarding the methodology used. These limitations may impact the results and should be taken into account when interpreting the findings. Three primary limitations stand out, each of which is described in detail below.

8.3.1. Qualitative methods constrain

While the qualitative approach used in this study is highly effective for examining map users' experiences and perceptions, it presents limitations in establishing causal relationships. As a result, the analysis of the connection between map usability, user perceptions, and the quality of risk communication media is grounded in the researcher' interpretations, supported by insights from previous studies. This study also does not identify which factors most strongly influence the effectiveness of the VSGM as a communication tool. Additionally, the impact of visual storytelling on enhancing geomorphological maps as a risk communication medium has not been quantified. For instance, it remains unclear how significantly visual storytelling elements, such as comics and instruction sheets, help users understand the geomorphological maps presented. This limitation arises from the absence of comparative data on the effectiveness of visual story-based geomorphological maps compared to those without a visual storytelling approach.

8.3.2. Interview process limitation

In this study, the usability testing of the VSGM was conducted immediately following its introduction to users, which may not fully represent real-world conditions. Typically, when a new communication tool is introduced, users require a training session to become familiar with its features and functions. Without this preparation, users may not have had the opportunity to explore the full potential of the VSGM, which could impact their ability to effectively interact with the tool during testing. Due to the time constraints of this study, a training session could not be implemented. As a result, the usability findings presented here may not fully capture the tool's performance in a real-world context, where users would likely have more time and guidance to adapt. However, despite this limitation, the results still offer valuable initial insights into the overall quality of the map design, providing a foundation for further evaluation and refinement.

8.4. Future research directions

Acknowledging the limitations of this study offers valuable insights into potential directions for future research. Addressing these limitations can help guide improvements and ensure a more comprehensive understanding of the role of storytelling in determining the effectiveness of geomorphological map for landslide risk communication. There are at least four key considerations for further research that could build on the current study's foundation and enhance the reliability and applicability of its findings. Each of these points is discussed in detail below to provide a clear pathway for future investigation.

8.4.1. The needs of quantitative methods

Future research need incorporate quantitative methods involving a larger sample size to strengthen the findings. While qualitative methods have provided valuable insights into the effectiveness of the VSGM as a tool for landslide risk communication, quantitative approaches can offer more robust data, particularly for assessing the significance of the VSGM model and identifying the factors that most influence its effectiveness. For instance, how does the VSGM compare to non-VSGM approaches in terms of user impact? As demonstrated by Kuster et al., (2023), who employed quantitative methods to compare the impact of two different geovisualization techniques on human flood risk perception.

Furthermore, which factors play a more critical role in determining the intention to use of VSGM—its cartographic design or user perception? For example, research by Huang et al., (2019) employed quantitative methods to examine which factors most influence middle-aged adults' attitudes toward health app usage, focusing on the relationship between users' cognitive, affective, and conative aspects. These inquiries could significantly enhance the understanding of the VSGM's role in landslide risk communication and improve the design quality for ensuring its future efficacy.

8.4.2. The use of advance technology for user-testing

The use of advanced technologies, such as eye-tracking, holds great potential for enhancing the quality of user testing data, particularly in evaluating map usability (Fairbairn & Hepburn, 2023). Eye-tracking technology can provide objective and detailed insights into how users interact with a map by monitoring their visual attention patterns (Dong et al., 2014). It captures where users look, how long they focus on specific elements, and the sequence in which their gaze moves across the map. This information can reveal critical usability issues, such as areas where users experience confusion or difficulty. For instance, if a user struggles with a tool on the map, their gaze may shift unpredictably, indicating uncertainty or frustration. Conversely, a smooth, focused gaze could suggest that the tool is intuitive and easy to use. Incorporating eye-tracking into future usability testing of the VSGM could lead to a more nuanced understanding of user interactions, allowing researchers to identify design improvements that might otherwise go unnoticed through traditional methods.

8.4.3. Expanding the type of map user

Future research on VSGM should focus on expanding the range of users and adapting the map design to their needs. Stakeholders in disaster risk reduction include not only disaster communicators but also teachers, local community members, and various government agencies beyond the National Disaster Management Agency (BNPB), such as the Ministries of Forestry, Agriculture, and Development Planning. Including a diverse sample of users in future studies would provide broader insights for refining the VSGM design and evaluating its effectiveness, ensuring it is optimized for different user groups and contexts.

8.4.4. Developing the digital version of VSGM

The next key direction for the future development of Visual Story-Based Geomorphological Maps (VSGM) lies in transitioning from traditional printed formats to digital platforms. This shift aims to significantly enhance the map's functionality and user engagement by embracing modern technological advancements. One promising avenue is the creation of interactive, web-based VSGMs that incorporate dynamic features such as real-time data integration, enabling users to access up-to-date information on landslide risks and conditions. Additionally, interactive elements could allow users to explore map features in greater depth, customize views based on their needs, and simulate various scenarios to better understand potential hazards and mitigation strategies. By leveraging these capabilities, digital VSGMs is expected to achieve the advantages of digital story map that can cater a wider audience, improve accessibility, and further empower users engagement (Berendsen et al., 2018).

Conclusion

This study highlights the essential role of geomorphological maps in landslide risk reduction while addressing their limited use by non-experts working as disaster communicator. To bridge this gap, storytelling approach was integrated into geomorphological maps to create a map design that presents complex scientific data in a more accessible format. The resulting design named Visual Story-Based Geomorphological Map (VSGM) emerges as an innovative communication tool designed for non-expert users, using Indonesia as a case study to assess its potential in enhancing landslide risk awareness and preparedness. This research not only documents the map-making process of the VSGM but also evaluates its effectiveness as a communication tool and outlines strategies for its future refinement and broader application. Specifically, this study focuses on addressing the following sub-objectives.

- **Sub-objective 1:** *Create a user-friendly design of VSGM using co-production technique*. The development of the VSGM involved collaboration with five disaster risk reduction professionals and two map users, emphasizing a user-centred approach to ensure practical utility. Using co-production techniques, the VSGM sought to accomplish two main goals: first, to enhance the design's quality and readability by integrating valuable input from both experts and end-users, thereby ensuring the map's accuracy and accessibility for a non-specialist audience. Second, by aligning the map's objectives closely with the needs of its users, positioned for future adaptability and sustained usefulness.
- **Sub-objective 2:** *Evaluate the cartographic quality of the VSGM design by analyzing its usability through semi-structured interviews*. Usability testing reveals that the VSGM demonstrates satisfactory cartographic quality, providing a user-friendly interface that allows users to easily navigate and discern its four primary purposes. Despite some challenges with understanding scientific terminology related to landslides, most users could effectively utilize the map to achieve its intended objectives. Specifically, they were able to locate landslide-prone areas, recognize factors contributing to landslides, understand designated landslide hazard zones, and apply this knowledge to design practical risk reduction

strategies for real-world contexts. This outcome underscores the effectiveness of comic, instruction sheet and derivative geomorphological map design in communicating complex scientific data to the non-expert users.

- **Sub-objective 3:** *Evaluate users' perception after using VSGM design by analyzing their Cognitive, Affective and Conative (CAC) using semi-structured interview.* A CAC study conducted after users' initial experience with the VSGM indicates that the tool successfully fosters a positive perception among users. While most respondents found the VSGM challenging to master, they reported high perceived usefulness and positive emotions, which motivate them to use and share it. Users felt that the VSGM holds meaningful value not only for themselves but also for the broader community. Additionally, they described the VSGM as an enjoyable tool and noted that it enhances their self-efficacy as disaster communicators. Although they may not yet feel fully confident using the VSGM independently, they expressed a willingness to invest time in training to develop proficiency, aiming to eventually use it without the need for expert support. These findings suggest that the VSGM not only improve user's knowledge (cognitive) but also give positive influence on the user emotion (affective) and behaviour (conative).
- **Sub-objective 4:** *Conduct a SWOT analysis to develop recommendations for the future enhancement of the VSGM as an effective tool for landslide risk communication*. Future development of the VSGM should focus on two critical areas to enhance its effectiveness and sustainability. First, addressing internal weaknesses related to map usability and users' perceived ease of use is essential. Research aimed at identifying more informative geovisualization techniques can support mapmakers in improving map usability. While designing supplementary materials to accommodate more detailed information, such as booklets, and holding regular training sessions with experts can increase user confidence and improve their perceived easy to use. Second, mitigating external threats that may affect the VSGM's efficacy is vital. Transitioning the VSGM to a digital format would enhance security, allow for timely updates, and enable wider dissemination to a wider area. Additionally, partnerships with domestic and international stakeholders could secure the necessary resources for ongoing VSGM production

and distribution, providing financial, technical, and logistical support to expand its use across multiple high-risk regions.

This research introduces a novel approach to enhancing the use of large-scale geomorphological maps for better landslide risk communication among non-experts. By integrating storytelling elements, such as comics and instructional sheets, with large-scale geomorphological maps, VSGM approach moves beyond traditional oversimplifications like landslide zoning maps, which often omit critical information. Instead, the proposed approach enhances the communication of detailed scientific data, allowing non-experts to fully leverage the benefits of geomorphological maps for disaster risk reduction (DRR). This innovative approach offers significant potential for adoption by scientists aiming to make their specialized maps accessible and meaningful for broader, non-expert audiences.

This study also advances risk communication by making specialized scientific maps more accessible and actionable for broader audiences. It emphasizes that maps designed for risk communication should go beyond simply conveying information to actively enabling users to address real-world challenges, ensuring their future utilization. The Visual Story-based Geomorphological Map (VSGM) exemplifies this approach by providing detailed insights into hazards and risks, enhancing understanding and local spatial knowledge, while simultaneously empowering users to develop site-specific DRR strategies. This dual-purpose design—integrating comprehension with practical application—boosts perceived usefulness, fosters positive emotional engagement, and motivates users to adopt and utilize the tool in the future.

While this qualitative empirical research offers a deep perspective on applying storytelling to popularize geomorphological maps for landslide risk communication, several limitations of the current study must be acknowledged. Although the qualitative approach provided in-depth insights into usability, it may have overlooked certain nuances, suggesting that future research could benefit from a mixed-methods approach to enhance validity. Quantitative methods, particularly those utilizing advanced technology such as eye tracking, can yield more objective and robust the usability data. These methods would also be valuable for evaluating the significance of storytelling in enhancing the effectiveness of geomorphological maps as landslide risk communication tools by comparing them with non-storytelling maps. Lastly, the local focus on landslide high-risk area in Indonesia limits the applicability of these findings to other regions with distinct geomorphological, demographic, and socio-cultural contexts, emphasizing the need to extend this research to diverse settings.

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Appendixes

Appendix 1. The transcript of the interview results with the supporting team during the co-production process.

Supporting member	Q: Will the VSGM objectives meet the user needs? Give reasons for your answer! Transcript
Geomorphological expert	Of course, if there is a media that can present geomorphological information on a detailed scale, it will be very useful for disaster communicators who are not geo-scientists. They need to understand the concept of hazard correctly. For example, currently, one of the things they really need is spatial information on the level of landslide activation, because it will be very helpful in determining the priority of disaster mitigation efforts.
Disaster management expert	I think yes. This VSGM will be very useful for the disaster communicator in Indonesia. Because most of them rely on theoretical books or brief expert lectures to grasp landslide hazards, risks, and mitigation strategies. However, the information they receive is generally framed in a global context, leaving a gap in resources that could aid their understanding in a more localized and practical manner for their area of work.
Geography education expert	I believe the VSGM serves the needs of disaster communicators without a geoscience background effectively. The map presents crucial hazard and risk information using accessible visualizations that are easy for non-experts to understand, making it a valuable resource for them
Learning media expert	I think yes. I believe that developing communication media like the VSGM, which bridges the gap between scientists and the community, is crucial. Especially in the context of disaster science in Indonesia. Currently, there is a shortage of site-specific educational tools like the VSGM that enable users to think critically about local issues in their own areas.
graphic illustration expert	Although I am not familiar with geomorphology, I firmly believe that media designed to connect scientists with non-experts is essential, especially in disaster management. This approach ensures that scientific advancements are accessible and beneficial to the community.
Map user 1	I would say yes absolutely. I greatly appreciate the effort invested in creating landslide risk communication media like this. It will significantly aid us in designing effective landslide mitigation strategies. We can present this in discussion forums with other agencies interested in disaster risk reduction, providing us with credible data to support our arguments.
Map user 2	Absolutely yes. In our office, the only map-based tool for landslide disaster communication is a district-level risk map. The maps provide very minimal information; they only indicate high- and low-risk areas, mainly for planning evacuation routes. When we're asked to recommend specific locations for mitigation efforts, like installing Early Warning Systems (EWS) or slope reinforcement, it becomes challenging because we don’t really know the landslide distribution very well, and we usually have to seek expert advice for that.

Appendix 2. Interview transcript with respondents and interpretation of map usability.

	Respon-dent	Transcript	Interpretation
Question 1	R1	E: Could you use this map to identify the location of landslides? R1: *Yes, I could. For example, this is one of the recent landslides, this is the scarp, and this is the body. I think the I can follow the symbols from the legend easily.	*Correctly answer without assistance.
	R2	E: Could you use this map to identify the location of landslides? R2: *Yes. This one (point out the landslide scarp) and this area is the landslide's body.	*Correctly answer without assistance.
	R3	E: Could you use this map to identify the location of landslides? R3: *Yes. This is landslides. Here as well (show the landslides symbols on the main map)	*Correctly answer without assistance.
	R4	E: Could you use this map to identify the location of landslides? R4: *Yes I can. This is landslide's body. This one is landslide' scarp. We can distinguish the scarp based on its height. This is scarp area with a height of more than 10m while this one is less than 10 meters.	*Correctly answer without assistance.
	R5	E: Could you use this map to identify the location of landslides? R5: *This is (pointing an active landslide symbols) an active scarp and its landslide's body. isn't it? E: Yes, it is	*Correctly answer without assistance.
	R6	E: Could you use this map to identify the location of landslides? R5: * Yes I can. This is an old landslide's scarp and its body. This is a recent landslide scarp.	*Correctly answer without assistance.
	R7	E: Could you use this map to identify the location of landslides? R7: *Yes, referring to the symbols in the legend. Most of this area are influenced by landslides process in the past.	*Correctly answer without assistance.
	R8	E: Could you use this map to identify the location of landslides? R8: *Yes, I can. This is landslide's scarp, and this is its body. Then there are many soil cracks as well around this area.	*Correctly answer without assistance.

Question 2	R1	E: Could you use this map to identify the difference type of landslides' activity? R1: Yes. There are two types of landslides' activity in this area. active and inactive landslide. This is the example of active landslides with its scarp and body, while this is the example of inactive landslide, this is the scarp (inactive landslide) and this is the body (inactive landslide).	*Correctly answer without assistance.
	R2	E: Could you use this map to identify the difference type of landslides' activity? R2: Landslides can be categorized as either inactive like this one or active, like this one. E: Oh, you mention a correct answer about the type of landslides, but you point out the wrong location*. all of them are inactive landslide. R2: Oh sorry, it is because the colour is almost the same. So, perhaps, this one is the active one. browner. E: Yes. It is. R2: I see. and I agree that new landslides tend to still be actively moving. From my experience installing Early Warning Systems (EWS), the pendulum of the EWS shows no movement for inactive landslides. However, for active landslides, when we review the data, there is still movement of about one to two centimetres.	* Correctly answer with assistance.
	R3	E: Could you use this map to identify the difference type of landslides' activity? R3: *This is a new landslide location that is still active with a scarp height of more than 10 meters, while this is a new landslide but has a scarp height of less than 10 meters. This light brown colour is an old or old landslide with a scarp height of more than 10 meters, while the line symbol but no triangle is an old landslide with a scarp height of less than 10 meters. Then these are the locations of the ground cracks	*Correctly answer without assistance.
	R4	E: Could you use this map to identify the difference type of landslides' activity? R4: *Yes, there are two types of landslides' activity. Inactive or old landslide and active or recent landslides. This is the example of landslide's body area, while this one is for recent landslide.	*Correctly answer without assistance.
	R5	E: Could you use this map to identify the difference type of landslides' activity?	*Correctly answer without assistance.

		R5: *Yes, like I did before. This is an active landslide; this is its scarp and body. This is an inactive landslide; this is the scarp and body.	
	R6	E: Could you use this map to identify the difference type of landslides' activity? R5: *Yes, there are two landslide's activities. An active or recent and inactive or old landslides.	*Correctly answer without assistance.
	R7	E: Could you use this map to identify the difference type of landslides' activity? R7: *Yes. This is a new landslide location, there is a scarp and its body. Then there is an old landslide scarp and its landslide body.	*Correctly answer without assistance.
	R8	E: Could you use this map to identify the difference type of landslides' activity? R8: ....(keep silent for 10 second) E: If you follow the 6th step in the instruction sheet, you can find the information about landslide's activity in the T1a frame. R8: Does it mean active and inactive landslide? E: Yes. R8: Oh, I see. So, this is an old and inactive landslide with a height of more than 10m, then this is a new or active landslide with a height of more than 10m. Then the new landslide body is in this area. while this area is an old landslide body.	* Correctly answer with assistance.
Question 3	R1	E: Could you explain the two landslides' type in this area using this map? R1: (keep silent 10 second) * E: If you follow the 6th step in the instruction sheet, you can find the information about landslide type in the T1b frame. R1: I see E: Then, could you explain it to me? R1: Hmm (keep silent 10 second) * E: Do you know about translational and rotational slide before? R1: No, I don't. * E: If you see these two pictures, do you see any difference between two of them? R1: hmm (keep silent 5 second), perhaps the numbers of soil cracks? this type of landslide (point out the rotational slide) has two, while the other one (translational) has only one. *	*Unable to answer correctly even with assistance.

		E: (explain the correct answer)	
	R2	E: Could you explain the two landslides' type in this area using this map? R2: *Landslide sliding surfaces can be either concave or straight, as shown in this image. Rotational landslides feature a concave sliding plane and typically occur on gentle slopes, whereas translational landslides have a straight sliding plane and usually happen on steep slopes.	*Correctly answer without assistance.
	R3	E: Could you explain the two landslides' type in this area using this map? R3: *There are several types of landslides, namely translational slides and rotational slides. The translational slide has straight sliding plane and commonly occurs in steeper slope, while the translational slide has curve sliding plane and commonly occurs in gentler slope.	*Correctly answer without assistance.
	R4	E: Could you explain the two landslides' type in this area using this map? R4: …....(keep silent for 10 second) * E: If you follow the 6th step in the instruction sheet, you can find the information about landslide type in the T1b frame. R4: I see. Hmm... what does rotational slide mean? I dont understand. * E: (help to explain)	*Unable to answer correctly even with assistance.
	R5	E: Could you explain the two landslides' type in this area using this map? R5: There are two types, right? There are rotational slides and translational slides. But I don't understand the difference. This is new information for me. * E: The difference between the two is in the shape of the sliding plane. Do you see the difference between the two? * R5: Oh, this one (rotational slide) has a concave sliding plane, while this one (translational slide) is straight. *	* Correctly answer with assistance.
	R6	E: Could you explain the two landslides' type in this area using this map? R6: what do you mean by landslides' type? * E: If you follow the 6th step in the instruction sheet, you can find the information about landslide type in the T1b frame. *	* Correctly answer with assistance.

		R6: *Oh, I see. The types of landslides found in this area are rotational landslides and translational landslides. Rotational landslides have a concave sliding plane and usually occur on gentle slopes, while translational landslides have a straight sliding plane and usually occur on steep slopes.	
	R7	E: Could you explain the two landslides' type in this area using this map? R7: *Yes, based on this picture, the type of landslides in this area can be in the form of rotational slide and translational slide. E: Could you explain the difference between those two types? R7: *Hmm. based on the information here, rotational landslides are formed due to the presence of a curved sliding plane and generally occur on gentle slopes, while translational landslides are formed due to the presence of a straight sliding plane and generally occur on steep slopes.	*Correctly answer without assistance.
	R8	E: Could you explain the two landslides' type in this area using this map? R8: ….... (keep silent for 10 second) * E: If you follow the 6th step in the instruction sheet, you can find the information about landslide type in the T1b frame. R8: …...... (keep silent for 10 second). * E: Can you find the information? R8: I am not sure, because I don't know if we can differentiate landslide into various type. * E: Oh yes, sis, so if you look at the information in this section (referring to the landslide type image on the map), the landslide type here can be identified as rotational and translational slide. you can also find the difference between two of them in this section.	*Unable to answer correctly even with assistance.
Question 4	R1	E: Can you explain some factors causing landslides in this area? R1: The pictures reveal multiple factors that cause landslides. Firstly, erosion at the foot of the slope by river flow reduces slope stability. Secondly, the presence of thick clay soil contributes to landslides; during heavy rain, water infiltrates the soil cracks and accumulates in the clay,	*Correctly answer without assistance.

		increasing the slope load and making landslides more likely. Additionally, human activities, such as slope cutting without proper retaining structures, can also trigger landslides in this area	
	R2	E: Can you explain some factors causing landslides in this area? R2: These photos illustrate several factors contributing to landslides in this area. First, the thick clay soil makes the area prone to landslides. Additionally, sparse vegetation leads to many cracks in the soil. The slope's foot is also eroded by river flow. For example, in the Bandongan area, the presence of a river below the slope decreases the slope stability, causing it to collapse. The lack of slope protection or vegetation around the river exacerbates this issue. Furthermore, slope cutting for roads has created numerous cracks, further increasing the likelihood of landslides.	*Correctly answer without assistance.
	R3	E: Can you explain some factors causing landslides in this area? R3: In addition to slopes, landslides are also caused by thick clay soil. Clay-textured soil is prone to cracking, allowing heavy rainwater to penetrate and increase the load on the slope, making it susceptible to movement. Active landslides can occur if the foot of the slope is eroded by river flow. Additionally, high slope loads from vegetation, houses, or roads can trigger active landslides. Slope cutting activities, as shown in this picture, can also trigger landslides. In general, landslides can occur due to natural or human factors.	*Correctly answer without assistance.
	R4	E: Can you explain some factors causing landslides in this area? R4: Yes, I can. First, the soil is thick and has a clay texture, which makes it easy for cracks to form on the slopes and hilltops. Then, the foot of the slope is eroded by the river flow, and this erosion process can accelerate landslides. The heavy load on the slope, such as dense vegetation, settlements, or roads, can also cause slope instability. Additionally, the process of cutting the slope to open new land can trigger landslides. As in the comic story, if slope cutting is done on an old landslide scarp, it can reactivate the old landslide scarp because the slope becomes unstable.	*Correctly answer without assistance.
	R5	E: Can you explain some factors causing landslides in this area? R5: As shown in the photos below, landslides in this area occurred due to the thick, clay-textured soil, which is prone to cracking. Another contributing factor is the presence of a river at the base of the slope, which gradually erodes it. Additionally, the slope may be overloaded by vegetation or	*Correctly answer without assistance.

		houses. Furthermore, residents cutting into the slope can also lead to instability.	
	R6	E: Can you explain some factors causing landslides in this area? R6: From these photos, it is evident that landslides in this area are caused by several factors, such as the thick, clay-textured soil and the numerous cracks in the ground. Additionally, the river flow erodes the base of the slope, making it unstable. Landslides here can also result from residents cutting into the slope for settlements, which steepens the slope and increases the likelihood of collapse.	*Correctly answer without assistance.
	R7	E: Can you explain some factors causing landslides in this area? R7: This is due to the very thick soil and the steep slopes in this hilly area. Additionally, river water flow erodes the base of the slope, making it unstable and prone to collapse. It could also be because the slope was excavated without proper planning, leading to numerous landslides.	*Correctly answer without assistance.
	R8	E: Can you explain some factors causing landslides in this area? R8:The landslide here was caused by the soil being more than 30 meters thick and having a clay texture, combined with the steepness of the slope. Additionally, erosion by river flow at the base of the slope contributed to its instability. Heavy slope loads due to vegetations, or houses also play a role. In this photo, it appears that slope cutting activities contributed to the landslide, though I'm not entirely sure why this causes landslides. * E: Oh, this is because slope cutting activities conducted without proper planning and protection can trigger landslides. Such cutting generally increases the slope gradient, making the slope more prone to landslides. R8: Thank you. I now understand. *	* Correctly answer with assistance.
Question 5	R1	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R1: Yes, this area (point out the red dash area symbol). it is in the area within and surrounding the active landslides. This is because active landslides have a higher likelihood of moving again in the near future compared to inactive ones.	*Correctly answer without assistance.
	R2	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others?	*Correctly answer without assistance.

		R2: Yes, in here (refers to the symbol of high potential area of landslide). I think it is because this area is within active landslide which has higher potential to move again in the near future.	
	R3	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R3: Perhaps this area (pointing to the symbol of the area that has the potential for landslides). It is because this area is an active landslide with a scarp height of more than 10 meters. then because there are also many cracks around it. If a landslide occurs in this area, it is likely to be quite large.	*Correctly answer without assistance.
	R4	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R4: Yes, I can. For example, this area is more prone to landslides because it is within an active landslide zone that has recently moved. Additionally, the river valley and gully are also more susceptible to landslides due to the erosion process, which can cause the slopes to become unstable.	*Correctly answer without assistance.
	R5	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R5: For example here (pointing to the symbol of the area that has the potential for landslides). Maybe because this is in an active landslide area that still shows signs of movement for the past few years. so it is more dangerous here.	*Correctly answer without assistance.
	R6	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R6: Areas within the potential landslide zone (indicated by the dash red line). it is because they are located in an active landslide area. As we know, active landslides are more dangerous than inactive ones because they are still moving.	*Correctly answer without assistance.
	R7	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others? R7: For example, this area, (pointing to an active landslide). This area is more dangerous perhaps because the landslide is still considered active.	*Correctly answer without assistance.
	R8	E: Can you point out areas with a high potential for future landslides and explain why you believe these areas have higher potential than others?	*Correctly answer without assistance.

		R8: for example, here, the area inside the red dotted line. This area has the potential for landslides because the slope is close to the river flow or gully. The river flow can erode the base of the slope over time, weakening it and potentially leading to instability and collapse.	
Question 6	R1	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R1: Settlements in this area (pointing to a residential complex). these settlements are at risk because they are located near a landslide hazard zone. If the slope collapses, it is likely to bury the houses here.	*Correctly answer without assistance.
	R2	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R2: Yes. Many areas are prone to landslides, but the most at risk is probably here, because it is close to residential areas and also here, because the active landslides have almost cut off the road network.	*Correctly answer without assistance.
	R3	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R3: For example, this area. If this area collapses, it will affect agricultural land, threaten settlements on hills and roads. Roads can be cut off and can have an impact on cutting off economic access.	*Correctly answer without assistance.
	R4	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R4: rephrase this If a landslide occurs in this area, the impact may be small because there are no houses or buildings around. Perhaps the most at risk is this area (pointing to another recent landslide). If this area collapses, it may cause a lot of damage because there are many houses or buildings above and below the scarp. Then if the gully wall erodes and collapses, this house could collapse.	*Correctly answer without assistance.
	R5	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R5: For instance, I believe this area is at higher risk due to the numerous settlements located in the high-potential landslide zone. If a landslide occurs, these settlements will certainly be impacted. Additionally, this area (pointing to the active scarp) is also at risk because continued land movement could potentially cut off access to village roads.	*Correctly answer without assistance.
	R6	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R6: Yes, I believe I can. For instance, this area is at higher risk because it contains many houses in a landslide-prone zone and is close to cutting off road access. In contrast, the	*Correctly answer without assistance.

		active landslides here are located far from residential areas, so they pose less risk of causing significant impacts.	
	R7	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R7: I think this area is more at risk (pointing to a residential area in a potential landslide area) if a landslide occurs in this area, it will impact settlements, road access, public facilities. In this location, the risk may be smaller because if a landslide occurs the impact is not too big because there are no houses around it.	*Correctly answer without assistance.
	R8	E: Can you use this map to point out the high-risk area for landslides? And explain why you choose that area? R8: This area is less at risk because there are no houses, so the impact of landslides would be minimal. However, if a landslide occurs in this other area, it will significantly affect the nearby settlements. Therefore, I believe this area has a higher risk of future landslides	*Correctly answer without assistance.
Question 7	R1	E: Can you design mitigation efforts to reduce the landslide risk using this map? R1: For example, I can use this map to identify where the Early Warning System (EWS) needs to be installed. The EWS should be placed on the upper slope, where the risk of landslides is high, perhaps here (pointing to a location). This area has a high landslide potential and many nearby settlements. Installing the EWS in the area marked by these red lines, symbolizing high-potential landslide zones, would be more effective.	*Correctly answer without assistance.
	R2	E: Can you design mitigation efforts to reduce the landslide risk using this map? R2: Certainly. For instance, if I were to install an EWS, I would place it here (pointing to the active landslide crown) to monitor land movement. Additionally, I would install an EWS to monitor river flow height at this point, given the numerous settlements on both sides of the river. We will also collaborate with related sectors such as PUPR, DLH, and forestry to ensure no further hill cutting. In areas with high population growth, proper protection plans are essential to reduce disasters if slopes must be cut.	*Correctly answer without assistance.
	R3	E: Can you design mitigation efforts to reduce the landslide risk using this map? R3: We can enhance safety by creating a protective cliff in this slope-cutting area prone to landslides (point out an area where there is a cut slope activity more than 5m). Additionally, installing landslide hazard signs before entering potential landslide zones will help residents	*Correctly answer without assistance.

		understand the risks they face (point out a settlement closed to high potential landslide area). Effective water management is crucial to prevent direct water flow into the escarpment, reducing erosion and the likelihood of future landslides. Strengthening ditch walls, perhaps by constructing embankments, can further mitigate erosion at the slope's foot (point out a gully wall near settlement). The village can also implement land use regulations and build safety embankments to reduce the risk of landslides. E: If this village can only have one EWS, where do you think it should be installed? R3: Probably in this area. There are many houses here and numerous cracks in the ground, so a landslide would have a significant impact. Installing it here (pointing to another area) would be less effective, as a landslide in that location wouldn't pose as much of a threat to residents' safety.	
	R4	E: Can you design mitigation efforts to reduce the landslide risk using this map? R4: First, I will convey the potential for landslides to the community, of course in a simpler way and adjusted to the community's understanding. Then close the cracks with soil and divert the flow of water so that it does not enter the cracks in the ground. It is also feasible to implement reinforcement structure on slopes that have been eroded by river flow area (pointing to an active landslide slope close to the river channel), possibly creating terraces using bamboo. Additionally, if feasible, implementing water flow diversion on landslide-prone slopes could help reduce erosion at the base of the slope. If an Early Warning System (EWS) is to be installed, I recommend placing it in this area, as a landslide here would have a significant impact due to its proximity to residential areas. In contrast, installing an EWS in this area (pointing to a location near active landslides) is less urgent since it would mainly affect agricultural land. However, protecting residential areas should be the higher priority.	*Correctly answer without assistance.
	R5	E: Can you design mitigation efforts to reduce the landslide risk using this map? R5: Yes, this map is useful for identifying locations that need to be restricted from development and designated as conservation areas. We need to avoid areas that are prone to future landslides. Additionally, if you want to build a slope retaining structure, this map can help. E: Where do you think the slope retaining structure should be built?	*Correctly answer without assistance.

		R5: For example, along this river wall, since the distance between the river valley and the residents' houses is very close. If this river cliff collapses, it could affect this house. E: I have a question. If an Early Warning System (EWS) is to be installed in this village, where should it be placed and why? R5: Perhaps in this area, because it is prone to landslides and has many houses. In that area (pointing to another area), although it is also prone to landslides, it is far from residential areas, so it does not become our priority. Saving lives must be our priority.	
	R6	E: Can you design mitigation efforts to reduce the landslide risk using this map? R6: Yes, for instance, we need to construct embankments on slopes that are prone to erosion by river flows, such as at this point (pointing to a gully cliff prone to landslides). Additionally, this can serve as a guideline for relocating settlements in landslide-prone areas. For example, residents in these settlements (pointing settlements within an active landslide’s body) should be more aware and be ready to move if the nearby slopes start showing many cracks in the ground.	*Correctly answer without assistance.
	R7	E: Can you design mitigation efforts to reduce the landslide risk using this map? R7: Yes, it can. For instance, when preparing a contingency plan, many variables need to be assessed. If we want to build temporary and permanent evacuation sites and routes, we should refer to this map. We must avoid placing them in active landslide areas or in zones marked by red lines that indicate potential future landslides. We need to find safer areas instead. This map can also help determine where to install Early Warning Systems (EWS). EWS should ideally be placed in landslide-prone areas with high population density, like here (pointing to a location). Installing EWS in less risky areas (pointing to another area) might not be a priority because there are no houses nearby. This map is very useful in prioritizing actions because, as Mr. Puji (founder of the NGO) said, needs are always unlimited, but resources are very limited.	*Correctly answer without assistance.
	R8	E: Can you design mitigation efforts to reduce the landslide risk using this map? R8: ….... (keep silent for 10 second) *	* Correctly answer with assistance.

		E: So, for example, if you were asked to recommend a safe location to build houses or public facility such as a school, where would it be? * R8: We need to avoid areas with active landslides and many cracks. For instance, avoid this area. E: And if you were asked to recommend locations for constructing embankments to prevent landslides, where would you suggest? * E8: I would recommend this area (pointing to a young landslide escarpment) because it is close to houses. Also, this area near the river should be considered, as the river flow is too close to the settlements. Embanking the river wall can prevent collapse. If asked to recommend the installation of an Early Warning System (EWS), it would be best to install it in areas with a high potential for future landslides and many nearby houses, such as here and here (pointing to settlements in potential landslide areas). In areas with potential for landslides that are far from settlements, installing an EWS might not be as crucial.	

Appendix 3. Interview transcript with respondents and the creation of "codes" related to perceived usefulness.

Respondents	**How important is this VSGM for landslide risk reduction measures? Please explain your reasoning.**	**Codes**
R1	This map is very important because [1]we can find out which areas that more susceptible to landslides. This map also provides an idea of slopes that have a higher potential for landslides compared to slopes that are relatively safer. [2]This comprehensive data is very important for determining appropriate residential zones and areas that should be avoided for massive development. Even though the potential for landslides is small, it is better to avoid them. *[3] From this map I could see the landslide locations and their characteristics, such as which ones were still active, and which were no longer active. I believe classifying the level of landslide activity like this will make it easier for me to identify which areas are more prone to future landslides. Naturally, areas around active landslides are more likely to continue moving compared to those that have been inactive for a long time* so that [4]it can be used as a reference for taking preventive steps to minimize the impact.	5 = very important [1]Identify area susceptible to landslides. [2]Suitability assessment for residential area [3]Shows landslide's location and characteristics [4]As a fundamental reference for taking preventive actions
R2	I strongly agree if this this map is very important because it assists us in improving disaster prevention planning, particularly [1]in determining suitable locations for installing Early Warning Systems (EWS). *Utilizing this map enhances my confidence in EWS placement decisions*. Additionally, due to its detailed information, [2]we can accurately identify potential landslide locations and [3]estimate their magnitude and impact. *Moreover, this map [4]facilitates discussions with other organizations, such as Public Works and Environmental Departments, enabling us to collaborate on implementing effective risk reduction strategies.* After studying it in more detail, it turned out that the map was different from the landslide hazard zoning map in our room. Firstly, this geomorphological map contains more detailed information and uses very specific terms that are very useful for managing landslides. For example, [5]we can see landslide locations and characteristics more precisely, so that the basis for determining landslide-prone areas becomes stronger. Then, this map can also be used to determine the location of Early Warning System (EWS) installation as we discussed earlier.	5 = very important [1]EWS placement decision [2]Identify area susceptible to landslides. [3]Estimate landslide hazard and its impact [4]Communication tool with other stakeholders [5]Shows landslide's location and characteristics
R3	Very important, because this map can [1]indicate areas that may be affected by landslides in the future, allowing disaster mitigation efforts to be focused in those areas. For example, we can [2]identify locations where landslide hazard signs need to be installed. Furthermore, this map assists in designing more precise mitigation efforts [3]tailored to the factors causing landslides in those areas. As mentioned earlier, landslides	5 = very important [1]Identify area susceptible to landslides. [2]Hazard sign placement decision

	here are largely caused by river flows eroding the slopes, so we need to [4]build slope reinforcement walls at vulnerable points. When [5]it comes to installing EWS, we can also use this map to determine more effective installation locations Beside It allows us to see the distribution and locations of these landslides, *This map is very useful for [6]showing the actual forms of landslides, such as their scarp and the bodies of the landslides*. The map also provides information about the height of the scarps and the slopes that are cut. [7]*The information about the height and area of slopes prone to landslides provided in this map is crucial for estimating how big a landslide could be and how far it might travel. So that, it helps us identify which houses, roads, or other assets are likely to be affected by landslides in the future.*	[3]Understand landslide causative factors [4]Slope reinforcement placement decision [5]EWS placement decision [6]Show landslide morphology in more detail scale. [7]Estimate landslide hazard and its impact
R4	*Yes, this map is very important, because if [1]we understand the potential disasters in our area, such as [3]knowing the types of threats and their locations, then we can take mitigation or anticipatory measures to reduce their impact. For example, [2]we can determine where to place slope retention walls and Early Warning Systems (EWS) to reduce landslide risk.* Then by using this map we gain an understanding of what potential disasters exist in the area, for example in this case the potential for landslides. When we know the threat and its location, we can take mitigating or anticipatory actions to reduce its impact	5 = very important [1]Identify area susceptible to landslides. [2]EWS placement decision [3]Show landslides characteristics and location
R5	For me it is very important. *I strongly agree and support the use of this geomorphological map [1]for spatial planning in disaster-prone areas*. It can help [2]identify safe area for constructing homes, roads, and public facilities, as well as where to implement landslide control measures. Therefore, this map is crucial for agencies like Bappeda or PU. *Moreover, it can [3]serve as a guide for environmental initiatives to carry out land conservation and reforestation that can reduce the risk of landslides. So that with geomorphological map, all disaster risk reduction activities can be carried out based on actual data.* This map, in my opinion, can provide very detailed data, such as the locations of landslides. Then there is information about land use as well, so we can [4]estimate the potential impact of the landslide. [5]there is also information about the characteristics of the landslide and [6]its causative factors, although there are still many terminologies that I heard for the first time	5 = very important [1]As a reference for spatial planning in disaster prone area [2]Suitability assessment for residential, road network, and public facilities area [3]As a guide for environmental initiative like land conservation and reforestation. [4]Estimate landslide future impacts [5]Show landslides characteristics [6]Understand landslides causative factors.
R6	Yes, it is very important, as the presented information is quite detailed, which can assist us in determining more specific mitigation steps. For example, earlier, as one of the contributing factors to the landslide was erosion from the	5 = very important [1]Slope embankments placement decision

	river flow, so one effective measure to minimize landslide hazards is to [1]construct embankments. *This map makes the mitigation steps and risk reduction more strategic* With this map we become aware of [2]landslide locations, both those that have occurred long ago and those that have recently occurred. The information on this map is very specific and detailed, enabling us to design more detailed mitigation measures. For example, [3]if one of the causes of landslides is riverbank erosion, the construction of embankments to reinforce the slopes along the river is necessary. Furthermore, when we [3]identify soil cracks, specific actions need to be taken. I'm not sure how to handle soil cracks, whether through planting vegetation or other methods, but what is certain is that mitigation measures need to be taken immediately upon realizing the presence of these cracks. [4]we can also identify settlement areas that are potentially affected by landslides in the future, then conduct analysis and consideration of whether relocation of these settlements is necessary or not.	[2]Shows landslide's location and characteristics [3]Understand landslides causative factors. [4]Estimate landslide future impacts
R7	Yes, this is clearly very important, but perhaps it should be supplemented with primary data from the community. However, this greatly helps me [1]understand the environmental conditions there, I now understand about 70% of it. This enables me to plan mitigation efforts, such as [2]determining priority areas for installing an Early Warning System (EWS). It can also serve as a reference to assess whether landslide mitigation measures such as vetiver grass would be effective or not. [3]For example, if the soil in this area is very thick, as you mentioned earlier, it seems that even vetiver grass roots might struggle to reach the bedrock beneath due to the thickness of the soil. Therefore, I believe this will greatly facilitate disaster planners. This map is very helpful in [4]visualizing the topographical features more realistically. So far, the landslide maps we've used in contingency plans are participatory maps, and sometimes there are areas that already have landslide maps based on GIS. However, matching participatory maps with GIS-based landslide maps can be quite challenging, as they have different symbols and scales, making it difficult to overlay them. [5]I think if we could accurately map the location and activity level of landslide like this, it would be very useful for assessing which areas are at greater potential for future landslides. For instance, we need to be more cautious of active landslides compared to old ones that haven't moved in a long time. Local residents living in the area may not have visited the entire village, especially for us foreigners who are asked to develop contingency plans in a particular area like me. So,	5 = very important [1]Understand the environmental condition [2]EWS placement decision [3]Understand landslides causative factors. [4]Provide more realistic terrain visualization [5]Identify area susceptible to landslides.

	having this geomorphological map will greatly assist us in visualizing the terrain conditions.	
R8	Yes, it plays a very important role. For example, [1]earlier we learned which areas have high potential to landslides and [2]Their impacts, then what the causes are, so we know how to reduce the danger and risks. This map also greatly aids in determining the location for [3]Installing Early Warning Systems (EWS), [4]Reinforcing embankments, or areas [5]To avoid for building houses *[6]After reading this map, I learned a lot about what causes landslides. Before, I thought landslides only happened because of elevation and slope. But now I know there are many factors, like thick clay soil that cracks easily, river flows eroding the base of the slope, or people cutting into the slope without careful planning and calculation.*	5 = very important [1]Identify area susceptible to landslides. [2]Estimate landslide future impacts [3]EWS placement decision [4]Slope embankments placement decision [5]Suitability assessment for residential area [6]Understand landslides causative factors.

Appendix 4. Thematic analysis results of "codes" related to perceived usefulness

Respondents	**Theme**				
	(1)	**(2)**	**(3)**	**(4)**	
	Show the landslides' location and their characteristics	**Explain landslides causative factors**	**Explain possible future scenarios of landslide hazards and impacts**	**Design mitigation efforts to reduce the disaster risk**	
				Structural	**Non-structural**
R1	[3]Shows landslide's location and characteristics		[1]Identify area susceptible to landslides		[2]Suitability assessment for residential area.
R2	[5]Shows landslide's location and characteristics		[2]Identify area susceptible to landslides. [3]Estimate landslide hazard and its impact	[1]EWS placement decision	[4]Communication tool with other stakeholders
R3	[6]Show landslide morphology in more detail scale.	[3]Understand landslide causative factors	[1]Identify area susceptible to landslides. [7]Estimate landslide hazard and its impact	[2]Hazard sign placement decision [4]Slope reinforcement placement decision [5]EWS placement decision	
R4	[3]Show landslides characteristics and location		[1]Identify area susceptible to landslides	[2]EWS placement decision	
R5	[5]Show landslides characteristics	[6]Understand landslides causative factors.	[4]Estimate landslide future impacts		[1]As a reference for spatial planning in disaster prone area [2]Suitability assessment for residential, road network, and public facilities area [3]As a guide for environmental initiative

					like land conservation and reforestation.
R6	[2]Shows landslide's location and characteristics	[3]Understand landslides causative factors.	[4]Estimate landslide future impacts	[1]Slope embankments placement decision	
R7	[4]Provide more realistic terrain visualization	[3]Understand landslides causative factors.	[5]Identify area susceptible to landslides.	[2]EWS placement decision	
R8		[6]Understand landslides causative factors.	[1]Identify area susceptible to landslides. [2]Estimate landslide future impacts	[3]EWS placement decision [4]Slope embankments placement decision	[5]Suitability assessment for residential area
	6	5	8	8	

Appendix 5. Interview transcript with respondents and the creation of "codes" related to Perceived easy to use

Respondent	**How easy is it for you to use this VSGM without the assistance of an expert like me? Please explain your reasoning.**	**Codes**
R1	Since I have only used this map once, educating people with it still feels quite challenging for me. Perhaps I will choose moderate as the level of difficulty. [1]I might need to practice with it a few more times before I really grasp everything it shows. Besides that, it's only focused on the Margoyoso area, so the information might vary in other areas. I think [1]attending a training session on reading maps two or three times would boost my confidence in using it without needing expert help. But *I find this comic really interesting because the visuals are quite illustrative and help explain the story, making it enjoyable to read. When I checked out the comic, I could already guess what I was going to learn*. So, to me, [2]this comic is like a prologue or an introduction that sets the stage before diving into the details of the geomorphological map.	3 = moderate [1]Additional training sessions are needed to boost user confidence in using the map. [2]The comic is like a prologue that sets the stage before diving into the map
R2	Sure, because the information on this map is very easy to understand. [1] Just by glancing at it earlier, I could already grasp it. Later, if there's specific training, it will be even easier to read. *This comic seems [2]to provide strong reasons why we should use geomorphological maps*. We learn how to solve problems that often occur in the field from comic stories. For example, learning from Pak Jalu's case, when he encountered obstacles or confusion in determining appropriate landslide disaster mitigation measures for his village, he went to the BPBD office and asked the officers. From this comic story, we realize that there are many sources that provide guidance in studying or managing disaster risks, one of which is through this geomorphological map. *So, by reading this comic, we become even more eager to understand geomorphological maps because these maps can address common problems encountered in disaster risk reduction measures.*	5 = very easy [2]The map is like a prologue that sets the stage before diving into the map [1]The map reading instruction is easy to follow
R3	I think this map is easy enough to use. Right now, [3]I think I can use this map by myself. But still, [1]I need to learn and practice more to increase my confidence level in using it. This comic is interesting and good. But perhaps the story sequences could be added. [2]This comic is very important for providing initial understanding of what geomorphological maps are and how they differ from geological maps. Then there are images and stories about the formation of old and new landslides, so when looking at the map, I already have knowledge and understanding of the terms used within it. Besides that, the main map is fascinating and highly informative, as well as easy to understand. [4]Since people generally prefer visuals over long texts, a photo or picture is often sufficient to convey meaning. For instance, take this photo	4 = easy [1]Several practice sessions are needed before I feel confident in using the map [2]The comic is like a prologue that sets the stage before diving into the map [3]The map reading instruction is easy to follow

	(pointing to the photo); it effectively illustrates that one cause of landslides is erosion on riverbanks	[4]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.
R4	[1]This comic helped me understand the terms in maps, such as what a geomorphological map is, what a scarp is, and so on. But, If I've only studied this map once or twice, I'm not fully capable of using it on my own yet. I would choose "moderate" for the easiness level. [2]But If I had a few more training sessions [3]along with detailed explanations, I might be able to use it in the future. I understood right away. [4]It's just that the explanation or narration is too detailed. However, I can understand the story, such as what village officials often face problems and [1]how this geomorphological map can be used to see potential landslides and design mitigation efforts. [5]Furthermore, *how this map is able to display the surface features of the Earth so clearly is something extraordinary.*	3 = moderate [1]The comic is like a prologue that sets the stage before diving into the map [2]Additional training sessions in map reading are still required [3]More detailed explanation about the terms in the map are still required. [4]The narration on the comic is too dense [5]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.
R5	I am still uncertain whether I can use it by myself or not, *because there is a considerable amount of information that I have only encountered once, like the various types of landslides and gully erosion, and others*. Therefore, [1]I may need additional time to study before feeling confident in using the map. So, this time I would choose "moderate" or level 3. However, this comic is highly beneficial as it provides insights into the importance of geomorphological maps in addressing various field-related challenges, as demonstrated by the experiences of the BPBD officer depicted in the story. Additionally, [2]the comic aids in the comprehension of numerous disaster and landslide terminologies through visual representations. Essentially, [3]the comic serves as a valuable prologue to exploring the map. *The overall concept of the story is interesting; however, [3]there is a need to simplify the text narration used in the comic in some part, as it appears to be overly dense.*	3 = moderate [1]Several practice sessions are needed before I feel confident in using the map [2]The comic is like a prologue that sets the stage before diving into the map [3]The narration on the comic is too dense.
R6	Honestly, if I were to use it now, I'm not confident enough to use it by myself, but [1]with some map reading training sessions, perhaps I could. *Because of the abundance of information in this map, I'm worried that there will be many questions from my audience that I won't be able to answer*. So, if there are [2]additional explanations or descriptions that can clarify the	3= moderate [1]Additional training sessions in map reading are still required

	images or terms in this map, it would be very helpful for me. If I have to choose, this map has moderate level of easiness. Actually, this comic has been quite helpful for me in understanding some terms that are displayed on the map, such as scarps, landslide bodies, and the sequence of relict and recent landslides. However, [3]the narrative could still be reduced, and the font size enlarged. Additionally, it's necessary to add sequential numbers to the storyline to make it easier to guide the readers. But overall, this is really good because it guides us in understanding the function of geomorphology and [4]what information we can expect to gain from reading this geomorphological map. *But if we talk about the map, it is quite easy to use. [5]This map is also equipped with pictures, illustrations and photos so that it helps me understand information that is still unfamiliar to me.*	[2]More detailed explanation about the terms in the map are still required [3]The narration on the comic is too dense. [4]The comic is like a prologue that sets the stage before diving into the map [5]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.
R7	[1]If the map is the same as this one and I follow the previous instructions, I'm sure I can manage it myself. The map is easy to use and understand because it includes comics and clear instructions. The benefit of this comic basically lies in [2]helping map users understand various terms displayed on the map. For users who are already familiar with landslide terminology, this comic may not be too important. *However, the reality is that many disaster educators are not yet familiar with specific disaster terms, especially those related to landslides. So, in my opinion, this comic needs to be read well in advance before reading the Geomorphological Map*. If necessary, it should be ensured that the user understands all the content of the story along with the terms that appear in the story before reading the Geomorphological Map. This can be done through some sort of simple competency test, so their knowledge is measured before and after reading the comic. Because actually, this comic is very helpful in understanding the map's function. So, *it's like a pocket guide; you need to understand it first before using the geomorphological map.* [3]Then *the 3D visualization on the main map makes it easier for me to understand the topographical features. I can imagine the shape of the landslide and the terrain at the mapping location, including the rivers and the size of the landslides, even without having visited the area before.*	5 = very easy [1]This map is easy to use because it is accompanied by a comic and an instruction sheet. [2]The comic is like a prologue that sets the stage before diving into the map [3]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.
R8	*I'm not entirely sure I can use the map without assistance from an expert yet. I feel capable because [1]I can understand how to read the map. I feel incapable because [2]there are still some terms that are unfamiliar to me, and I've just learned about them now. So, I'm a bit less confident if asked to explain again. Basically, [3]I still need time to learn more*. So I will choose number 3.	3 = moderate [1]The map reading instructions and the comic storyline are easy to follow.

	However, *this comic is very interesting. Because of this comic, I no longer feel lazy to read*. Additionally, there is a lot of new information presented. This illustrated comic assists me in understanding new information such as landslide scarps, gully erosion, and others.	[2]More detailed explanation about the terms in the map are still required [3]Several practice sessions are needed before I feel confident in using the map

Appendix 6. Thematic analysis results of "codes" related to perceived easy to use

Participant	**(1)**	**(2)**
	Easiness	**Difficulties**
R1	[2]The comic is like a prologue that sets the stage before diving into the map	[1]Several training sessions are needed to boost user confidence in using the map
R2	[2]The comic is like a prologue that sets the stage before diving into the map [3]The map reading instruction is easy to follow	
R3	[2]The comic is like a prologue that sets the stage before diving into the map. [3]The map reading instruction is easy to follow [4]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.	[1]Several training sessions are needed to boost user confidence in using the map
R4	[1]The comic is like a prologue that sets the stage before diving into the map [5]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.	[2]Several training sessions are needed to boost user confidence in using the map [3]More detailed explanation about the terms in the map are still required.
R5	[2]The comic is like a prologue that sets the stage before diving into the map	[1]Several training sessions are needed to boost user confidence in using the map
R6	[4]The comic is like a prologue that sets the stage before diving into the map [5]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.	[1]Several training sessions are needed to boost user confidence in using the map [2]More detailed explanation about the terms in the map are still required
R7	[1]This map is easy to use because it is accompanied by a comic and an instruction sheet. [2]The comic is like a prologue that sets the stage before diving into the map [3]The 3D illustration and photos on the main map aid in visualizing the realistic representation of geomorphic features.	
R8	[1]The map reading instructions and the comic storyline are easy to follow.	[2]More detailed explanation about the terms in the map are still required [3]Several training sessions are needed to boost user confidence in using the map

Appendix 7. Interview transcript with respondents and the creation of "codes" related to positive and negative emotion

Respon-dent	**Do you agree if this VSGM can enhance your capability as a disaster communicator? Please explain your reasons.**	**Codes**
R1	I strongly agree. Indeed, as educators specializing in disaster preparedness, [1]it is crucial for us to be able to identify disaster-prone regions and understand their specific characteristics. [2]*This map could potentially serve as an innovative tool for instructors like us to impart valuable education to the public*, utilizing inventive geomorphological maps. [3]*Besides that, I find this comic really interesting because the visuals are quite illustrative and help explain the story, making it enjoyable to read.*	5= very agree [1]Increase capability in identifying landslide-prone area. [2]Provide new tools to educate people [3]The comic is very interesting and enjoyable.
R2	I totally agree because [1]*this map makes things much easier for us, especially when we work in the disaster prevention and preparedness projects. For example, by Utilizing this map it will enhances my confidence in making EWS placement decisions.* [2]The information in the map gives us valuable knowledge for educating or reaching out to people living in areas prone to disasters. It will make our work much more straightforward and efficient. [3]Moreover, this map facilitates discussions with other organizations, such as Public Works and Environmental Departments, enabling us to collaborate on implementing effective risk reduction strategies.	5= very agree [1]Increase confidence in EWS placement decision [2]Provides new knowledge [3]Facilitates discussion with other stakeholders
R3	Very agree because [1]we can understand the potential for both old and current landslides. [2]we can inform residents about the locations of hazardous areas. I hope they can minimize activities or construction that could trigger landslides and pose a threat to their safety. [3]Besides that, this comic is interesting and good	5= very agree [1]Provides new knowledge [2]Increase confidence to inform people about hazardous area [3]The comic is very interesting and enjoyable.
R4	I completely agree, [1]because with this map, the process of identifying landslide-prone areas will become much easier. Like the information in the map earlier, we can pinpoint landslide locations more precisely. We can even identify the locations and shapes of old landslides that are covered by vegetation. [2]Furthermore, *how this map is able to display the surface features of the Earth so clearly is something extraordinary.*	5= very agree [1]Increase capability in identifying landslide-prone area. [2]Help to imagine the earth's surface morphology
R5	I strongly agree because *I rarely encounter a map that can display data and information as detailed and comprehensive as this one. As I mentioned earlier, [1]this map provides me with a lot of information and new knowledge.*	5= very agree [1]Provides new knowledge

R6	I totally agree, [1]especially this map will assist me in explaining the potential of landslides in the field and [2]determining more strategic and suitable mitigation steps. Furthermore, [3]this provides me with new knowledge, for example, it turns out that landslides have various types, and I now understand their differences, such as between rotational and translational slides. Additionally, this map is also equipped with diagrams, illustrations, and photos, thus aiding me in understanding information that is still unfamiliar to me	5= very agree [1]Increase capability in identifying landslide-prone area. [2]Increase capability in determining more strategic mitigation measures. [3]Provides new knowledge
R7	I totally agree. As I mentioned earlier, [1]even though I have never visited Margoyoso village or the mapped area, and I have no understanding of the situation there, after reading this map, I now understand the situation and conditions there. I can imagine what the topography looks like, the shape of the rivers, and the shape and location of previous landslide occurrences in that area	5= very agree [1]Help to imagine the earth's surface morphology
R8	I totally agree. [1]besides providing a lot of new knowledge such as type of landslides causative factors, [2]this map will greatly assist me in explaining the landslide potential. *It's much easier to explain using a medium like this geomorphological map compared to explaining directly without any visual aid*. Later on, the community can directly see the map. [3]Besides that, *this comic is very interesting. The story and illustration are good, I don't feel lazy to read."*	5= very agree [1]Provides new knowledge [2]Increase capability in identifying landslide-prone area. [3]The comic is very interesting and enjoyable.

Respond-ents	**Do you agree if the general public need to know and understand this VSGM? Please explain your reasons.**	**Code**
R1	I agree that the local community need to be introduced about this geomorphological map. Still, it might be easier to introduce it to young people, [2]because maybe those in their 40s and above would find it difficult to understand such a map. Perhaps [1]we can target young people or disaster educators at the district to village level.	4 = agree [1]This map will be beneficial for disaster educators at the district to village level. [2]This map will be difficult for people over 40 years old to understand
R2	[2]If the general public referred to here are local residents, they may encounter difficulties. This is because, considering their human resources, many villagers still have difficulty reading due to their low levels of education and experience. However, I strongly agree [1]if this map is understood by personnel or employees of the Village and Sub-district who deal with disaster issues. So, they are the ones we need to train to read this map. Hopefully, they will have better insights into disasters and can convey important information in this geomorphological map to	5 = very agree [1]This map will be beneficial for the frontline community who are responsible for DRR at district to village level. [2]This map will be difficult for local people to understand

	local residents in simpler language. But the main point is, I strongly agree if more people understand this map.	
R3	I strongly agree, [1]especially for people living in hazardous areas. If they can absorb the important information in this geomorphological map, hopefully, they will prioritize environmental safety aspects when building houses or utilizing land	5 = very agree [1]This map will be beneficial for people living in hazardous area
R4	Agreed, especially for the general public who live in disaster-prone areas. [2]However, perhaps the discussion about the map needs to be simplified further. Because the understanding concept between the general public and academics is different. Maybe the presentation should be more simplified	4 = agree [1]This map will be beneficial for people living in hazardous area [2]This map will be difficult for local people to understand
R5	I completely agree. [1]In my opinion, this map is important for disaster facilitators, both from the government and NGOs. [2]However, *If I share all this information to the local people, this map seems too complicated to understand. Besides, if they see this kind of information, I'm afraid it will scare them because we are also not sure how likely this area will be to landslide.*	5 = very agree [1]This map will be beneficial for disaster communicator, both from government and NGOs [2]This map will be difficult for local people to understand
R6	I do agree, [1]especially for disaster practitioners. [2]However, perhaps not all members of the general public, for instance, for the local community, the information might need to be further simplified.	4 = agree [1]This map will be beneficial for disaster practitioners [2]This map will be difficult for local people to understand
R7	I strongly agree [1]*if this map needs to be understood by the general public, especially those living in disaster-prone areas. [2]However, the complexity of the map may need to be simplified because I believe the general public would still struggle to understand this extensive data.* For example, the scarps symbols do not need to be differentiated into more than 10 meters and less than 10 meters. They can be merged instead. [1]However, I believe understanding this geomorphological map is important for people living in the landslides hazardous area, even at the level of neighborhood unit. At least the head of the neighborhood or hamlet should understand this map, then they can deliver the important information to all the residents."	5 = very agree [1]This map will be beneficial for head of hamlet and communities concerned with DRR at the neighborhood level. [2]This map will be difficult for local people to understand
R8	I strongly agree. [1]In my opinion, communities living in disaster-prone areas as well as disaster volunteers need to understand maps like this.	5 = very agree [1]This map will be beneficial for people living in hazardous area and communities concerned with DRR

Appendix 8. Thematic analysis results of "codes" related to positive and negative affect

Respondent	Positive affect				Negative affect
	(1)	(2)	(3)	(4)	(4)
	Meaningful	**Self-efficacy**	**Worthwhile**	**Enjoyable**	**Worrisome**
R1	[2]Provide new tools to educate people	[1]Increase capability in identifying landslide-prone area.	[1]This map will be beneficial for disaster educators at the district to village level.	[3]The comic is very interesting and enjoyable.	[2]This map will be difficult for people over 40 years old to understand
R2	[2]Provides new knowledge	[1]Increase confidence in EWS placement decision	[3]Facilitates discussion with other stakeholders [1]This map will be beneficial for the frontline community who are responsible for DRR at district to village level.		[2]This map will be difficult for local people to understand
R3	[1]Provides new knowledge	[2]Increase confidence to inform people about hazardous area	[1]This map will be beneficial for people living in hazardous area	[3]The comic is very interesting and enjoyable.	
R4	[2]Help to imagine the earth's surface morphology	[1]Increase capability in identifying landslide-prone area.	[1]This map will be beneficial for people living in hazardous areas		[2]This map will be difficult for local people to understand
R5	[1]Provides new knowledge		[1]This map will be beneficial for disaster communicators, both from government and NGOs		[2]This map will be difficult for local people to understand [3]The detailed information on this map can cause fear in the community
R6	[3]Provides new knowledge	[1]Increase capability in identifying landslide-prone area.	[1]This map will be beneficial for disaster practitioners		[2]This map will be difficult for local people to understand

		[2]Increase capability in determining more strategic mitigation measures			
R7	[1]Help to imagine the earth's surface morphology		[1]This map will be beneficial for the head of hamlet and communities concerned with DRR at the neighborhood level.		[2]This map will be difficult for local people to understand
R8	[1]Provides new knowledge	[2]Increase capability in identifying landslide-prone area.	[1]This map will be beneficial for people living in hazardous area and communities concerned with DRR	[3]The comic is very interesting and enjoyable.	
	8	**6**	**8**	**3**	**6**

Appendix 9. Interview transcript with respondents and the creation of “codes” related to willingness to share

Respon-dent	**Will you eager to disseminate this VSGM to your colleagues? Please elaborate on your reasons and specify the recipients.**	**Codes**
R1	Yes, It is very likely. I will suggest sharing this geomorphological map with [1]other disaster educators. Because, learning how to read it can help identify areas where landslides are more likely to occur. It might also be helpful to show it to [2]BPBD staff at different administrative levels, such as provincial, district, and city. From what I've seen, the details in this map can be really useful when staff are teaching local communities about the risk of landslides in their area.	5= very likely To whom: [1]disaster educators [2]BPBD stuff at different administrative levels (provincial to Regency/City)
R2	Oh, absolutely yes. Once this map is officially released, I will recommend it to my colleagues in the disaster management office, especially the BPBD offices across Central Java and throughout Indonesia because we are interconnected, working together in disaster management, and sharing information. We will demonstrate how important the geomorphological map is for disaster management or risk reduction.	5= very likely To whom: [1]BPBD staff throughout the country
R3	Of course Yes, I will recommend this map especially to colleagues who share the same job as me. Because in the [1]BPBD, where our duties involve information and communication, there are six personnel, so I think everyone needs to understand this map. This map offers insight into the types of data we need to collect to identify landslide-prone areas. Additionally, I also recommend it to [2]Village officials who assist us in the field, as they have a better understanding of potential threats in their areas. Furthermore, perhaps this map can be used by the village head and their staff to establish regulations that can reduce disaster risks, especially landslides.	5= very likely To whom: [1]BPBD staff, especially who work in information and communication management centre. [2]Village officials
R4	Yes, I will highly recommend it to my colleagues. Firstly, [1]to each Disaster Response Team (TRC) in the districts prone to landslides. For example, in Borobudur, Salaman, and Kaliangkrik districts. Then, to [2]the members of the OPRB or Disaster Risk Reduction Organization in every village in Magelang Regency. So, this map can be used as a tool to increase their capacity in understanding the potential for landslides in their respective areas. Additionally, perhaps [3]to village or district officials who are primarily responsible for disaster management, as disaster management essentially returns to the concept of the "blue triangle", where disaster management issues become the responsibility of the community, government, and business sectors.	5= very likely To whom: [1]Disaster Response Team (TRC) at districts levels. [2]member of Disaster Risk Reduction Organization (OPRB) in every village. [3]Village officials.
R5	I highly recommend this map to [1]my colleagues, particularly those working at PU, as they are often involved in constructing roads, bridges, or slope-strengthening structures. Additionally, I would recommend it to my peers [2]at BPBD or within my current institution, as I believe it could serve as a valuable educational tool for them. It's important for [3]disaster volunteers who assist us in managing disaster-related issues in villages to also familiarize	5= very likely To whom: [1]Staff of Public Works and Public Housing (PUPR)

	themselves with this map. Furthermore, I intend to suggest this map to governmental bodies responsible for spatial planning, such as [4]the Forest Agency and [5]Bappeda. I believe the comprehensive information provided by this map would offer them significant benefits, including aiding in the identification of areas for conservation and safe locations for development centres within villages.	[2]Staff of Development Planning Agency at Sub-National Level (Bappeda) [3]Staff of Forest Management Agency. [4]BPBD staff [5]disaster volunteers
R6	I highly recommend it for my BPBD stuff, in my opinion. Because the information on this map is different from what we usually use. As I mentioned earlier, the information is very detailed and specific, thus providing a realistic picture of the earth surface conditions. Additionally, this map is also accompanied by comics and map reading instructions. Well, even though I was a bit confused earlier, with frequent readings, this might become easier for us to understand.	5= very likely To whom: [1]BPBD stuff
R7	Yes, I highly recommend it, especially for resilient community-based disaster facilitators. According to the information I have now from the readiness catalogue website, there are at least 7,000 facilitator groups, whether they are village-level facilitators from BNPB, prepared villages from the Ministry of Health, resilient coastal villages from the Ministry of Maritime Affairs, or whatever their name may be, as long as they are facilitators working at the community level. If they can understand this map, I think it would be very beneficial	5= very likely To whom: [1]disaster facilitators at community or village level. Such as DESTANA community and more rhan 7000 communities all around the country
R8	I would highly recommend this map [1]to my colleagues who also work as disaster educators. Because currently, we are working on a project to enhance the capacity of communities and government officials in dealing with landslide disasters in several areas. So, I believe this map will enhance our knowledge and understanding as disaster educators	5= very likely To whom: [1]Disaster educators

Appendix 10. Thematic analysis results of "codes" related to willingness to share

Respondents	**I would recommend this map to…**		
	my workmate	**the other institutions**	**DRR community**
R1 (BPBD staff)	[2]BPBD stuff at different administrative levels (provincial to Regency/City)		[1]disaster educators
R2 (BPBD staff)	[1]BPBD staff throughout the country		
R3 (BPBD staff)	[1]BPBD staff, especially who work in information and communication management centre.		[2]Village officials
R4 (BPBD staff)			[1]Disaster Response Team (TRC) at districts levels.

			[2]member of Disaster Risk Reduction Organization (OPRB) in every village. [3]Village officials.
R5 (BPBD staff)	[4]BPBD staff	[1]Staff of Public Works and Public Housing (PUPR) [2]Staff of Development Planning Agency at Sub-National Level (Bappeda) [3]Staff of Forest Management Agency.	[5]disaster volunteers
R6 (NGOs)		[1]BPBD stuff	
R7 (NGOs)			[1]disaster facilitators at community or village level
R8 (NGOs)	[1]Disaster educators		

Appendix 11. Interview transcript with respondents and the creation of "codes" related to willingness to use

Respon-dents	**Will you utilize this VSGM in the future? Please explain your reasons and specify the purposes for which you will use it.**	**Code**
R1	Yes, It is likely. I think I could include this map [1]as part of our educational materials for our "Destana" or Desa Tangguh Bencana program. In "Destana," we teach how to map areas prone to landslides, and this map could be a valuable madia for identifying landslide areas. This map contains more detailed and clearer symbols that can show area of active landslide and high risk of landslides. However, if my audience is local people such as elderly and children, maybe I can't immediately use this map as it is.	4 = likely [1]Teaching/instructional media
R2	Yes, for sure. I will use this map if it has been officially released. Perhaps, [1]Iwill use it for discussions with the local government of Magelang Regency and the operational control center at BPBD. Currently, the good quality map that we have is the hazard map for Mount Merapi. So, after a brief review and learning, it turns out that this geomorphological map is exceptionally specific and will be very beneficial for landslides management and control in the field.	5= very likely [1]Discussion tools
R3	Yes, of course. [1]I will definitely use it for my own needs, especially to support my work in the field of disaster data and information management. This includes enhancing my insights and knowledge about the types of data needed to collect for landslide risk analysis. Additionally, it adds to my understanding when I am asked to be a disaster educator in villages. Because it	5= very likely [1]Learning resources [2]Discussion tools

	seems that if I bring this map directly to the residents, they will have difficulty understanding it. They usually take a long time to learn how to read maps. They generally entrust map matters to us as BPBD officers. [2]However, I might also bring it when discussing with village officials, as they are the ones who usually make decisions regarding disaster management programs in their area.	
R4	Maybe, I will choose number 4. I will use it when [1]discussing with my colleagues, such as disaster response team and village officials. But if with the general public like local people, it seems that this map is still too difficult to use because there are elderly people and children.	4 = likely [1]Teaching/instructional media
R5	It is likely. I might [1]utilize this map during discussions in forums with government officials or disaster educators. However, if I were to engage with local people, it may be necessary to further simplify the map.	4 = likely [1]Discussion tools [2]Teaching/instructional media
R6	Wow, that would be great. Of course I will definitely use it. Please, when the map is finalized, just give it to me immediately. Because just like I said earlier, this map [1]can be an alternative medium when discussing landslide hazard potentials with my audience, perhaps with disaster practitioners or local government officials.	5= very likely [1]Discussion tools
R7	Yes, It is likely. Maybe you can go with number 4 or 5. Because, when my audience is the local community or villagers, this map needs to be simplified, and the information should not be as complex as it is now. It needs conceptualization according to the specific region, ma'am. [1]But when my audience consists of participants from other NGOs, private companies , local government such as BPBD, village facilitators, or fellow educators, I can use this map directly.	4 = likely [1]Discussion tools [2]Teaching/instructional media
R8	Perhaps yes. If my audience consists of schoolchildren and elderly individuals, it seems challenging to teach using this map. However, if my audience comprises fellow volunteers, I can use this map. [1]Alternatively, teachers in schools might be able to use it since I am also working as an educator to help develop Disaster-Safe School Units (Satuan Pendidikan Aman Bencana - SPAB) in elementary, junior high, and high schools.	4 = likely [1]Teaching/instructional media

Appendix 12. Thematic analysis results of "codes" related to willingness to use

Respondent	I intend to use this map as it is for			I need to simplify this map before using it as
	my learning resources	discussion tool	teaching media	teaching media
R1 (BPBD staff)			[1]I will use this map to teach the DRR community	[2]I need to simplify this map for local people, the elderly, or children
R2 (BPBD staff)		[1]I will use this map in the discussion forum on landslide risk management with the local government		
R3 (BPBD staff)	[1]I will use this map to improve my work in disaster data collection and management.	[2]I will use this map in the discussion forum on landslide risk management with the local government		[2]I need to simplify this map for local people, the elderly, or children
R4 (BPBD staff)		[1]I will use this map in the discussion forum on landslide risk management with my colleagues or local government.		[2]I need to simplify this map for local people, the elderly, or children
R5 (BPBD staff)		[1]I will use this map in the discussion forum on landslide risk management with disaster facilitator or local government.		[2]I need to simplify this map for local people, the elderly, or children
R6 (NGOs)		[1]I will use this map in the discussion forum on landslide risk management with disaster practitioners or local government.		
R7 (NGOs)		[1]I will use this map in the discussion forum on landslide risk management with other NGOs, private companies, or local government.	[2]I will use this map to teach the DRR community or village facilitators.	[2]I need to simplify this map for local people, the elderly, or children
R8 (NGOs)			[1]I will use this map to teach teachers at schools	[2]I need to simplify this map for local people, the elderly, or children

Appendix 13. Ethical Clearance

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ETHICS COMMISSION APPROVAL

No: KE/UGM/073/EC/2023

Research Protocol Title	:	*Co-Production of Disaster Risk Communication Instrument: A Visual Story-Based Geomorphological Map for Understanding Landslide Hazards in Indonesia*
Approved documents	:	Research proposal 02 2023 version Explanation to prospective subjects dan *Informed Consent Form* 01 2023 version
Principle investigator	:	Prof. Dr. Junun Sartohadi, M.Sc.
Participating researchers	:	1. Elok Surya Pratiwi, S.Si., M.Sc. 2. Dr. Su-Min Shen
Date Approved	:	14 Desember 2023 (valid for 1 year from the date of approval)
Research institution/places	:	Daerah Istimewa Yogyakarta dan Provinsi Jawa Tengah

The Research Ethics Commission of Universitas Gadjah Mada states that the above document meets the standards of research ethics principles.

The Research Ethics Commission of Universitas Gadjah Mada has the authority to supervice research activities at any time.

Principal researchers are required to submit:

- ☐ Research progress report
- ☐ Special report if there is serious incident
- ☑ Final report when the research has been completed.

Panel Chair	Panel Secretary
Dr.biol.hom. Nastiti Wijayanti, M.Si.	Dr. Devi Oktaviana Latif, S.T., M.Eng.

Supplementary data related to this research (mostly in Chapter 4) are available from the author upon request.

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