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Indigenous science disaster risk reduction: A conceptual model integrated learning in Indonesian elementary schools

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Article info

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Abstract

As a vulnerable group, elementary school students need to be directly involved in disaster risk reduction through learning at school. Local wisdom in disaster risk reduction, bridging the gap with modern risk reduction. This study aims to produce a model in science learning by using local wisdom learning resources for disaster risk reduction. The data analysed were articles focused on local wisdom in Indonesia using qualitative meta-analysis. The data source is articles published in indexed journals by Scopus, with the criteria of selected articles (research or review) related to local wisdom in disaster risk reduction in Indonesia. The research findings are that (1) indigenous communities have original cognitive thinking skills for responding to disasters and (2) a conceptual science learning model based on indigenous knowledge to train students' responses to disasters. Disaster risk reduction by directly involving vulnerable groups (elementary school students) provides benefits: students will learn about disasters, understand actions before a disaster occurs, understand the process of saving themselves when a disaster occurs, and be directly involved in emergency response.

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1. Introduction

Indonesia is a region that has a very high potential for natural disasters (Warsito et al., 2021), both geological and hydrometeorological disasters. Several geological disasters occurred, which caused massive infrastructure damage and many victims, such as the eruption

of Mount Agung in Bali (Syahbana et al., 2019), the eruption of Mount Merapi (Bakkour et al., 2015), and the eruption of Mount Sinabung (Sullivan & Sagala, 2020), earthquakes and tsunamis in Aceh (Syamsidik et al., 2021), Palu (Harnantyari et al., 2020), Lampung (Samson & Warganegara, 2021) and Lombok (Koopman, 2023). Besides geological disasters, it is also vulnerable to disasters caused by climate change (Gan et al., 2021), such as floods, droughts, landslides, and tornadoes. Furthermore, those most affected by this disaster are vulnerable groups. Vulnerable groups are populations with special characteristics (elderly, pregnant women, children, and special needs) who are at high risk (health, economic, and social) due to disasters (Isia et al., 2023) and need to receive serious attention. Children, especially elementary school students, are the largest population potentially affected by disasters because the impact of disasters has a significant effect on children's psychological conditions in the form of post-traumatic stress disorder (Powell et al., 2021).

For this reason, strategies are needed to reduce the impact of disasters by reducing disaster risks through education with integrated and inclusive steps to increase preparedness and recovery responses and strengthen resilience. Systematic steps in the education process, especially learning about disaster risk reduction, are strongly influenced by several variables. Using approaches, models, methods, media, and learning tools in learning disaster risk reduction in schools significantly influences students' knowledge about disasters and the actions taken before and after a disaster (Suarmika et al., 2022). Innovative forms of disaster risk reduction learning can also be integrated into the school curriculum (Gong et al., 2021), the use of digital technology (Nagata et al., 2022), game-based learning (Tsai et al., 2020), and integrated with religion (Suyadi et al., 2020). Apart from formal education, DRR is also implemented in non-formal (Seddighi et al., 2023) and informal education (Bernhardsdottir et al., 2016).

The efforts carried out by the government and academics regarding DRR in elementary schools need to be reviewed because the results or achievements of disaster risk reduction education are still far from expectations. The fundamental problem is that; disaster risk reduction education programs or projects are only incidental and ceremonial, so consistency and continuity of socialization and education are needed whether there is or is not a disaster (Tahmidaten & Krismanto, 2019); the level of knowledge, preparedness, and disaster mitigation efforts of elementary school students was relatively low (Hafida, 2019) and the anxiety level of children affected by earthquake disasters was in the standard and clinical categories (Thoyibah et al., 2019). Several factors cause non-optimal learning for disaster risk reduction in elementary schools: disaster risk reduction education is a discovery in the world of education, and there is a gap between government and regional government policies that hinder DRR Education (Kitagawa, 2021). There are no systematic and concrete actions to include disaster content in the learning curriculum in schools, disaster themes and categories of words/phrases related to disasters (danger, vulnerability, disaster risk, protection, safety, landslides, earthquakes, volcanic eruptions, tornadoes, tsunamis, mitigation, evacuation, early warning) are found in the curriculum (Atmojo, 2019),

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As such, incorporating local wisdom is necessary to integrate disaster risk reduction into learning appropriate to the student's context regarding potential disasters in the student's environment. One of the lessons in elementary school that can be integrated with DRR and local wisdom is science. Science learning aims to study phenomena and events and build theories through scientific investigations (Hodson, 2014) as well as develop problem-solving skills related to global issues (Blatti et al., 2019) to interpret messages received and respond to opportunities and challenges (Hammond et al., 2020). This can provide interesting topics for students while encouraging them to explore the local wisdom behind scientific phenomena (Zidny et al., 2020). Local wisdom as a learning resource (Basuki et al., 2019), which is integrated into science learning, influences character development (Khusniati et al., 2017), scientific literacy (Setiawan et al., 2017), and the environment (Ilhami et al., 2019), scientific process skills and attitudes (Rosa et al., 2020), scientific communication skills (Dewi et al., 2019) and critical thinking (Wirawan et al., 2021). There are similar patterns and mechanisms between indigenous science and indigenous disaster knowledge, which grows from the experience of indigenous people to survive by adapting to environmental conditions. Therefore, it is deemed necessary to integrate local wisdom into the learning.

2. Method

This study uses a qualitative approach with a meta-synthesis type, which synthesises research findings with complex interpretations to find a deeper core or meaning (Sandelowski et al., 1997) with transparent analytical, interpretative, and symbolic techniques (Sandelowski & Barroso, 2003). This method is used to explore the form of local wisdom in Indonesia based on published research results. The data source of this study is articles published in indexed journals by Scopus, with the criteria of selected articles (research or review) related to local wisdom in disaster risk reduction in Indonesia. The selected articles were published in 2005, assuming that disaster risk reduction in Indonesia began after Aceh's earthquake and tsunami disaster in 2004.

The research's primary goal is to discover how the patterns and elements form local wisdom in reducing disaster risk. The data analysis technique uses multistage deep interpretative analysis with the stages of data analysis being: (a) repeatedly reading the primary articles; (b) grouping into themes about disaster risk reduction; (c) determining categories based on themes, as a form of scientific interpretative results; and (d) determining patterns or models of relationships between disaster risk reduction and sciences based on local wisdom obtained from interpreting the theme.

The research's second objective is to construct a theoretical framework for science learning in elementary schools, which also aims to create habits in reducing disaster risks based on the local wisdom of the Indonesian people. The data analysis model is the reconstruction of interpretive theory with the following stages: (a) analysis the first findings in more depth or second deep analysis to find relevant elements in learning; (b) analysis of learning needs in elementary schools including the science learning curriculum and the main

objectives of disaster risk reduction; and (c) design a theoretical framework by integrating indigenous science with indigenous DRR based on students' learning needs.

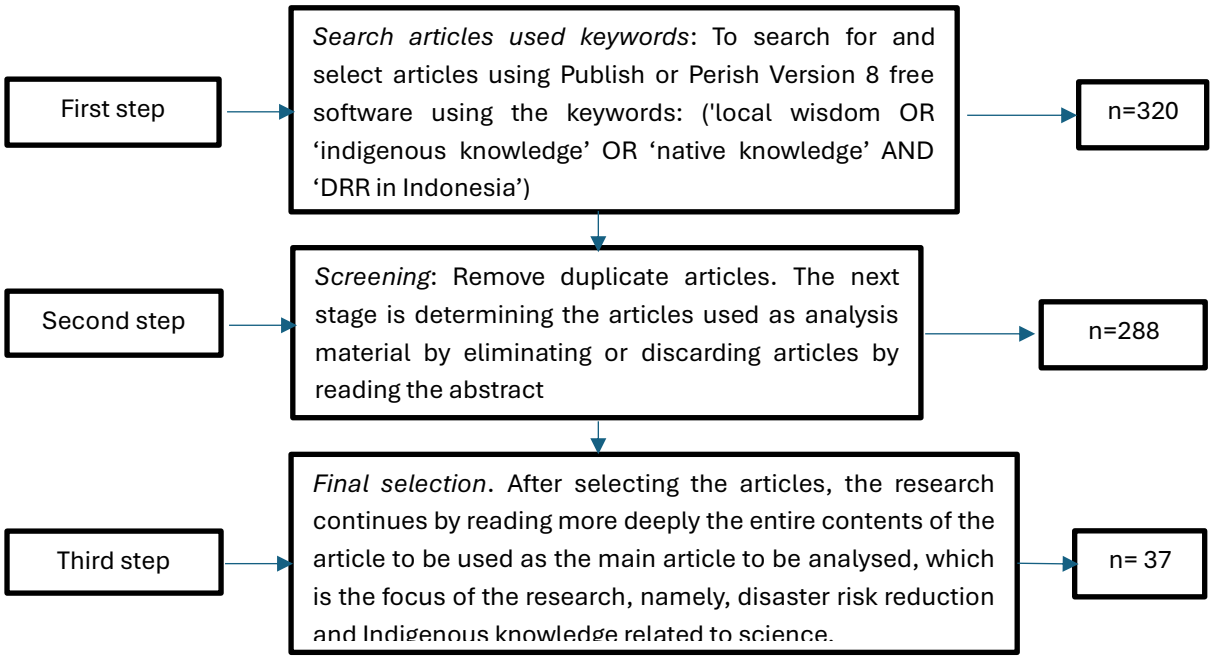

Figure 1. Data article selection process

3. Results

3.1 Indigenous intangible *in Situ*

Indigenous intangible *in Situ* is a form of unwritten local wisdom based on regional conditions (potential disasters) and the social relations of Indigenous communities. Ancestors pass it down to the next generation through oral tradition. This form consists of belief and knowledge. Beliefs related to disaster risk reduction are the causes of disasters with (a) *Disharmonious Relationships*, such as the people of Kuta Village believe in the existence of spirits considered to be messengers of God Almighty (Hilman et al., 2019). Indigenous communities believe that disasters occur due to a bad relationship between nature, humans, and the creator; (b) *Deliberate Negligence*, such as *Pamali*, *Maduanganalo*, *Mabulisapa* and *Torosapa* (Wani & Ariana, 2018; Marlina et al., 2020). The belief that disasters occur for the community is a form of asymmetrical relationship based on the cause and effect of actions carried out by humans themselves and not caused by natural factors; (c) *Carrying Out Rituals to ask for safety*, such as *Batang Garing* (tree of life) and *Memapas Lewu* (Usop & Rajiani, 2021). The form of asking for safety is carried out with a ceremony; if the ceremony is not carried out, it is believed that it will cause a disaster.

The second type is knowledge, which consists of factual and procedural information. Factual knowledge related to disaster risk reduction is detailed information about natural signs of impending disaster (strange animal behavior, plant behavior, sudden environmental changes,

microclimate changes, and movements of celestial bodies) (Marlina et al., 2020; Haris et al., 2019; Permana, 2020; Syahputra, 2019; Naping et al., 2019) and sources of danger (a place or area that has the potential to pose a threat to oneself or others) (Titisari et al., 2019; Rindarjono et al., 2018; Lubis et al., 2021; Wibowo et al., 2021). Meanwhile, procedural knowledge related to disaster risk reduction is the real steps taken before a disaster occurs (direct preventive measures to potential disaster sources) (Riptanti et al., 2018; Yuliana et al., 2017; Surtikanti et al., 2017; Yasir et al., 2022; Fajarwati & Masruri, 2019; Murhaini & Achmadi, 2021; Nopriyasman et al., 2024) when a disaster occurs (self-rescue measures) (Gadeng et al., 2018; Suarmika et al., 2020; Griffin & Barney, 2021; Fakhriati et al., 2023) and after a disaster (emergency response measures) (Hastuti et al., 2022).

3.2 Indigenous tangible *in Situ*

Local wisdom, in the form of products, consists of technology and manuscripts. Technology related to disaster risk reduction is a product that performs those functions as protection from the threat of danger (wild animals, changing weather conditions, disasters), namely houses with materials sourced from nature (Setyowati, 2017; As'ari et al., 2019; Wahyuningtyas et al., 2019; Darusman, 2020; Naing & Hadi, 2020; Firdaus et al., 2023). Additionally, technology is available to warn of danger using traditional communication tools (Zulfadrim et al., 2018). Manuscripts related to disaster risk reduction in the form of records of experiences agreed upon by Indigenous communities, based on experience to be agreed upon and implemented together, which contain procedures for agriculture, social relations, and disaster mitigation (Limpo et al., 2022; Karjanto, 2022; Koopman, 2023). This knowledge produces products based on observations about potential disasters and the methods used to reduce their risks. This means that the situation stimulates thinking to produce products to survive the threat of disaster.

3.3 The conceptual model of indigenous DRR through science learning

Based on the findings of Indigenous intangible and tangible in situ, a conceptual model for integrated disaster risk reduction learning in elementary school science learning can be designed to accustom students to be responsive when a disaster occurs. This conceptual model is an alternative model for teachers in elementary school learning, which consists of the main components, namely students' prior knowledge (local wisdom), learning content (Indigenous DRR and science), and learning activities. Meanwhile, integrated science disaster risk reduction objectives into science learning outcomes, because DRR is not a separate curriculum but can be achieved in the learning process. This framework's advantage is that it invites students (as vulnerable groups) to be directly involved in facing disasters with the following three phases.

Phase I

The following activities explore students' prior knowledge about disasters (knowledge and risk reduction) and indigenous science (local wisdom knowledge). *Teacher activity* is that

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teachers design projects or events with the theme of disasters and science; projects or events can be in the form of film screenings, simulations (disaster management agencies), and arts and cultural performances; and projects or events are carried out at the end of the semester or the beginning of the school orientation period. *Student activity* is active as project or event participants; expressing experiences about these activities (in the form of notes or essays); and telling or writing down initial knowledge related to disasters and local wisdom.

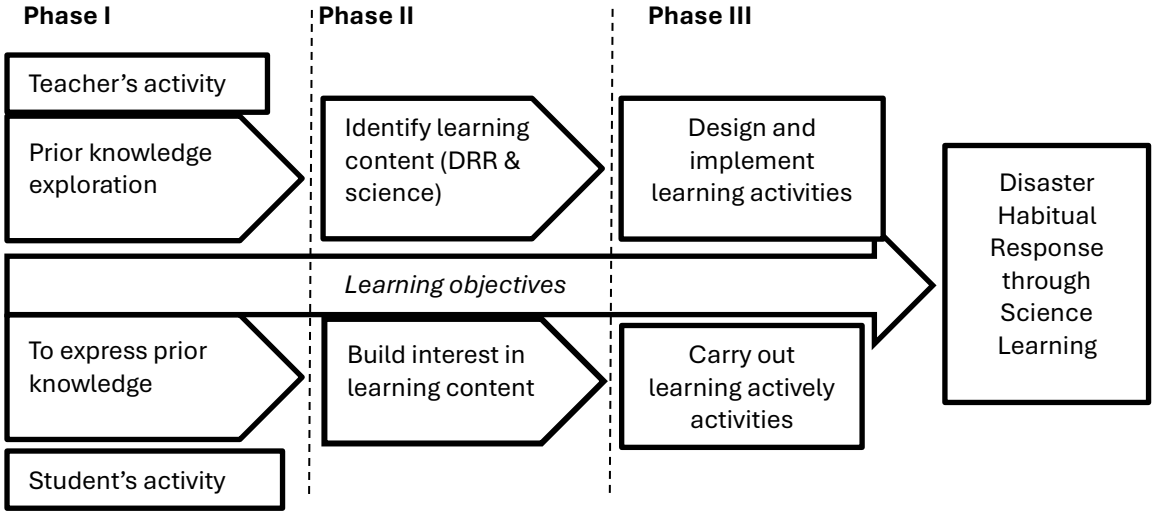

Figure 2. Models of Indigenous Science for Disaster Risk Reduction Learning

Phase II

Learning content readiness is a pre-learning activity that determines the achievement of science learning integrated with disaster risk reduction learning (before, during, and after a disaster). Science learning achievements are *biodiversity*, *classification*, *and processes and mechanisms of living things*; *ecology, environment*, *and conservation of natural resources*; *mechanics*; *state of matter*; *electricity and magnetism*; *waves and optics*; *temperature and heat*; *forms of energy and their changes*; *Earth, solar system and space*. Disaster risk reduction learning outcomes are *knowledge of types and mitigation*; *rescue and evacuation actions during disasters*; *post-disaster actions* (emergency response). The following *teacher activities* are: 1) learning interventions by strengthening students' beliefs about disasters and reducing their impacts through science learning; 2) providing examples of local wisdom as a form of disaster mitigation and containing elements of science; and 3) Identifying science learning outcomes related to disaster risk reduction based on local wisdom (see Table 1). The activities carried out by teachers are expected to build interest in science learning integrated with disaster risk reduction. Selection with analysis of appropriate science learning outcomes is the primary key to making learning more meaningful to students, as disasters cannot be predicted, but their impacts can be reduced. With the criteria of local wisdom as Indigenous Science:

a) Beliefs related to the indigenous scientific attitude are that the attitude is a way or method for Indigenous people to maintain relationships (with God, nature, and humans) by obeying customary rules and acting honestly and responsibly.
b) Factual knowledge related to indigenous science products is where indigenous people understand the concept or theory of the role and function of living things with non-living components (biotic and abiotic).
c) Procedural knowledge is related to the indigenous scientific process, namely, using inherited experience to solve problems with measurable steps before concluding.
d) Local wisdom in the form of technology is also related to indigenous science products, namely the application of simple scientific concepts.
e) The form of manuscripts is also related to indigenous process science, namely, applying scientific processes through simple experiments based on local empirical contextual experiences.

Table 1. Indigenous science-related western/modern science (A number of examples)

Indigenous Science	Western/ Modern Science Content
Umpung sidom lagee nyan cit. This means that ants also move to higher ground before the flood, and if the ant nests are spread across the ground, it indicates that a flood will come soon (Syahputra, 2019).	*Living things and the environment*. Some animals can sense an impending disaster by detecting environmental changes, pressure differences, electric shocks and running to higher ground to protect themselves individually or in colonies.
Indigenous communities have designed and constructed stilt houses (*Rumah Gadang, Rumoh Aceh, Joglo, Omo Hada*) with the base of the house having a base (above the ground surface) to support the main pillars of the building, and the main frame of the building is interconnected (Kurnio et al., 2021).	*Mechanics*: application of the concept of friction force by using building pillars not embedded in the ground, so that when an earthquake occurs, it will release energy into the air below.
The building materials for Bugis tribal houses are wood, which is used for the pillars and frame, and palm leaves for the roof (Naing & Hadi, 2020).	*Temperature and Heat*: Using building materials from plants keeps the temperature inside the house cool because wood is a heat insulator
The presence of gas provides clues to its toxicity. Topographic depressions on the lower slopes of the Timbang crater can act as gas outlets in the event of an eruption and should be avoided if conditions are dark, cloudy, or foggy (Griffin & Barney, 2021)	*State of matter*: Applying the concept and principles of changing the state of matter from liquid to gas (evaporation).
In the *Lontara Allaorumang* book, it is written that when the crescent moon appears, it faces north and occurs from the first night to the seventh night, indicating that there will be many wet days and heavy rain that year (Limpo et al., 2022).	*Earth, Solar System, and Space*. The concept of the Earth's rotation and revolution in the solar system results in climate change, namely the rainy and dry seasons.

Phase III

Science learning and disaster risk reduction are systematic and structured activities so that the learning process can be done in and outside the classroom. Classroom learning focuses on exploring students' understanding of science as a product and training problem-solving and critical thinking skills using scientific methods integrated with disaster risk reduction, with local wisdom learning resources. Learning outside the classroom focuses on applying skills in disaster reduction (disaster simulation). *Teacher activities* consist of 1) designing learning plans with identified science learning outcomes and disaster risk reduction; 2) the learning process uses a student-centred learning with learning resources in the form of local wisdom on disaster risk reduction that contains elements of Indigenous science with learning steps; activate students' prior knowledge, provide problems or disaster events to be analysed from a scientific perspective, analysis is carried out with guided or independent group work, present the results of the analysis, provide space to reflect on the results of the analysis; and 3) assessment of the learning process using formative and summative models with the aim of how far students' performance in achieving learning objectives.

This model framework emphasises local wisdom in science learning in elementary schools. Areas that lack local wisdom can adapt or adopt forms of local knowledge from other regions by considering the potential for disasters. If it is difficult, local knowledge can be ignored (using other learning resources, such as the environment, web-based learning, and modern disaster risk reduction).

4. Discussion

The research findings indicate that indigenous communities can survive based on the conditions of their region with complex thinking (scientific and non-scientific integration). The emergence of knowledge and technology for disaster risk reduction comes from indigenous people's learning to recognise, respect, and maintain the environment in which they live. This proves that indigenous people had a method of thinking by learning from nature until modern terms were discovered.

Belief is an important component in disaster risk reduction. Indigenous people firmly believe that the cause of disasters does not occur naturally but is due to human error. In principle, if a problem (disaster) occurs, humans are the cause, and a solution must be sought to avoid disaster. This belief results in an agreement or rules of Indigenous people carried out together to guide community life. Cultural beliefs and social norms greatly influence people's responses to disasters (Karlsson et al., 2019). Local beliefs play an essential role and have an existential function for humans (Izzuddin et al., 2022). Religious beliefs and practices are paramount in dealing with disasters to provide emotional and social support to those affected to recover (Gianisa & De, 2018).

Indigenous disaster knowledge combines Indigenous communities' attitudes, concepts, and applications in predicting and preparing for disasters. Communities have specific ways or methods of using indigenous knowledge in facing disasters and emergencies (Hadlos et al.,

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2022). This finding confirms that Indigenous knowledge comes from human thinking to overcome problems (disaster threats) according to their environment and social relationships. Indigenous knowledge and practices can strengthen the reduction of the risks caused by natural disasters (Ali et al., 2021). This knowledge is transmitted orally, through observation and practice, in a dynamic process to meet the needs of a particular community (Silva et al., 2024).

Indigenous knowledge about disasters can be integrated into modern disaster risk reduction. Indigenous knowledge (rituals, experiences, and familiar stories reinforced through trial and error) is a phrase used to describe information collected over many generations. It is mostly only available in oral form (Ullah et al., 2024). This means that knowledge gained through trial and error can be scientifically analysed as relevant to potential disasters. Combining local and scientific knowledge in the education system and creating community-based programs also helps to improve the local people's integration and knowledge (Hermans et al., 2022). Figure 2 explains that the conceptual model uses local wisdom (indigenous knowledge) in science learning in elementary schools to train students' scientific thinking skills. This process emphasises the integration of local knowledge to be connected and validated based on the concept of Western science to explain phenomena with a scientific approach (Reid et al., 2021; McAllister et al., 2023). Western science makes contributions that give birth to technology, but also has limitations, and indigenous knowledge plays a role (Mazzocchi, 2018). Learning by integrating local and Western scientific perspectives helps students' insights (Zidny & Eilks, 2020).

Local wisdom used as learning resources needs to be adapted to the local student culture. Therefore, the teachers' role is to carefully choose the form of local wisdom in science learning in elementary schools. In the learning process, students analyse local wisdom, for: who, how, to whom, why, and its impact (Bang et al., 2018); learn to be collaborative, relational, spiritual, respectful, and responsive (Datta, 2016); develop aspects of attitude, knowledge, and skills (Handayani et al., 2018); and train and develop critical responsiveness (Bullen & Roberts, 2019). Integrating local knowledge through social and ecological wisdom is essential to facilitate knowledge transposition and didactics in disaster education (Noviana et al., 2023).

5. Conclusion and Implications

Indigenous peoples have a unique way of thinking when solving problems, especially in disaster risk reduction. A way of thinking prioritises a cosmological and ecological approach passed down from generation to generation. The results of this thinking produce a culture, namely local wisdom (indigenous knowledge), which is still maintained until now. Disaster risk reduction by directly involving vulnerable groups (elementary school students) will provide benefits, such as students will learn about disasters, understand actions before a disaster occurs, understand the process of saving themselves when a disaster occurs, and be directly involved in emergency response. The formal learning process (science) by integrating, adapting, adopting, and accommodating local wisdom (Indigenous science and DRR) will make learning more meaningful.

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6. Limitation

This study has several limitations. First, the data analysed came from scientific articles with a disaster context in several regions of Indonesia that focused on local wisdom. As such, several forms of local wisdom that are missed may have more effective disaster risk reduction methods (field studies). Second, the indigenous science DRR learning framework is a scientific conceptual model that can be used as an alternative to learning in Elementary Schools. For this reason, empirical evidence is needed to apply learning tools to see the framework's effectiveness.

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