

Bridging Theory and Risk Reality: Gap Analysis of Disaster Mitigation Competencies in Indonesian Civil Engineering Education Curriculum

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Abstract

Amidst the increasing intensity of natural disasters in Indonesia, the role of civil engineers has evolved from merely designing physical structures to becoming crucial agents in disaster resilience. However, there is a clear discrepancy between the technical-static nature of civil engineering higher education curricula and the dynamic and multidisciplinary needs of disaster mitigation in the field. This study aims to diagnose this competency gap through a Systematic Literature Review (SLR) method using the PRISMA 2020 protocol. Data were collected from the Dimensions, Scopus, and Web of Science databases, resulting in 10 selected articles that were analyzed thematically. The results revealed that the main gap lies not in structural calculation abilities (hard engineering), but in deficits in “soft” competencies such as risk communication, policy advocacy, and post-disaster management. This study also identified that conventional (didactic) teaching methods are ineffective and recommended the adoption of new pedagogical strategies such as Forensic Engineering and humanitarian project-based learning. This research offers a curriculum mapping framework as a strategic solution to integrate disaster management competencies without overburdening the existing curriculum, in order to produce civil engineers who are resilient and responsive to risks.



Keywords: Civil Engineering Education; Disaster Risk Reduction (DRR); Curriculum Gap Analysis; Engineer Competencies; Forensic Engineering.

INTRODUCTION

The construction and civil engineering sectors play a central role in determining the level of disaster risk in a region, given that physical structural failure is often the main cause of loss of life and massive economic losses when natural hazards occur (Bosher & Dainty, 2011). Although the global framework has explicitly mandated the integration of disaster risk reduction principles into every stage of infrastructure planning to ensure sustainable resilience, technical implementation in the field is often still hampered by development approaches that are less adaptive to hazard scenarios (UNDRR, 2015). Therefore, the modern civil engineering paradigm requires professionals to not only focus on cost efficiency and material strength, but also to be able to incorporate the concept of “built-in resilience” into their designs in order to anticipate future threats (Bosher & Dainty, 2011).

Effective implementation of Disaster Risk Reduction requires strict compliance with multi-hazard building codes to ensure the operationality of critical infrastructure during crises, but this success absolutely requires a strong bridge between technical standards and urban governance policies (World Bank, 2015). The biggest challenge often lies not in the absence of engineering technology, but in the failure to translate technical risk parameters into development regulations that can be understood and executed by stakeholders at the local level (Djalante et al., 2017). Therefore, the role of modern civil engineers can no longer be limited to construction calculations alone; they are required to have advocacy skills to communicate the findings of structural vulnerability audits to public administrators, so that safety standards can be transformed into tangible and binding spatial policies (World Bank, 2015).

The unpreparedness of the formal curriculum creates a real irony of competence, where civil engineering students are often forced to rely on general information or mass media coverage as their main source of disaster knowledge, rather than obtaining it from structured learning modules (Park et al., 2025). This dependence on informal sources has a serious impact on the depth of their technical understanding; although students may be fluent in discussing the concept of resilience as a theoretical discourse, they often fail when required to translate the concept into specific and functional engineering design decisions (Tyas et al., 2025). As a result, graduates tend to have fragmented expertise—proficient in mathematical calculations of structural components, but clumsy in designing infrastructure systems that are holistically capable of adapting and



recovering from disaster shocks (Park et al., 2025)

The competency gap at this level of education contributes directly to crisis management inefficiencies in the field, where response failures are often not caused by a lack of technological resources, but rather by the unpreparedness of human resources to manage the complexity of emergency situations (Alexander, 2005). To break this chain of failure, disaster management literature emphasizes the need to shift from a static knowledge-based curriculum to an adaptive competency-based framework, which adopts international standards such as ISO 22320 to ensure interoperability and command effectiveness (Alexander, 2005). However, the main challenge in implementing this global standardization into the local context is institutional resistance and practitioners' lack of understanding of how to align rigid international protocols with flexible local socio-cultural dynamics (Chmutina & Rose, 2018).

In the context of technical higher education in Indonesia, there is a fundamental gap where the current curriculum is still dominated by a technocratic approach that focuses heavily on physical structure calculations (hard engineering), but lacks training in managerial and social aspects of disaster management (soft competencies). Research on the post-disaster construction industry in Indonesia shows that many engineers and project managers are at a loss when faced with disaster recovery situations, not because of technical incompetence, but because of a lack of understanding of community-based approaches and adaptive risk management (Ophiyandri et al., 2013). Conventional civil engineering curricula in Indonesia tend to treat disasters as external loads in formulas, rather than as dynamic variables that require integrated spatial planning and mitigation (Amri et al., 2017). As a result, graduates often have partial competencies; they are able to design earthquake-resistant buildings individually, but lack strategic insight into how such infrastructure interacts with broader regional vulnerability systems (Nistor & Palermo, 2015).

Although academic literature has extensively discussed the importance of disaster education, the focus of existing studies tends to be fragmented and targets preparedness at the elementary education level or the general public, while critical evaluation of civil engineering higher education curricula—as the main actors in development—remains very limited and has not been systematically mapped (Adiyoso & Kanegae, 2012). The absence of a specific evaluation framework allows the “competency gap” to widen, where higher education institutions risk continuing to graduate engineers who are technically proficient but clueless in responding to the dynamic reality of disaster risk, a condition that directly contributes to the long-term vulnerability of national infrastructure (Wibowo & Alfen, 2015). Responding to this urgency, this study aims to fill the literature gap through an in-depth Gap Analysis, which seeks to diagnose specific



discrepancies between the existing curriculum content and the mitigation competencies required by the industry. This study not only aims to expose academic deficits, but also offers concrete pedagogical integration strategies to transform Indonesian civil engineering education: from being merely oriented towards physical structural strength, to holistic education that bridges engineering precision with risk management acumen for sustainable public safety.

METHODOLOGY

This study applies a qualitative approach through the Systematic Literature Review (SLR) method to investigate, evaluate, and synthesize empirical evidence regarding the integration of disaster curriculum in civil engineering education. The research protocol was designed strictly following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and minimization of bias in drawing conclusions. The data collection process was conducted comprehensively through globally reputable academic databases, with Dimensions as the primary data source selected for its broad coverage of citations and research grants, which was then triangulated with data from Scopus and Web of Science (WoS) to ensure high bibliometric validity. The literature search strategy used specific Boolean syntax, combining keywords related to the field of education ("Civil Engineering Curriculum," "Engineering Education") and the field of disaster management ("Disaster Risk Reduction," "Emergency Management"), with a temporal limitation on publications from the last 10 years to capture the relevance of current technology and pedagogy.

The document selection process was carried out through a multi-level screening mechanism, starting with initial identification to remove duplication between databases, followed by title and abstract-based screening to eliminate contextually irrelevant articles. Articles that passed the initial stage were then evaluated for suitability through full-text review based on strict inclusion criteria, namely that the literature must be peer-reviewed journal articles or conference proceedings that explicitly discuss pedagogical models, student competency evaluation, or analysis of civil engineering curriculum gaps in the context of disaster mitigation, and be available in English or Indonesian. Data from the selected literature is then extracted and analyzed using Thematic Analysis techniques, where findings are categorized to map the gap analysis between current curriculum outputs and the competencies demanded by the industry, the final results of which are synthesized into recommendations for an adaptive curriculum framework.



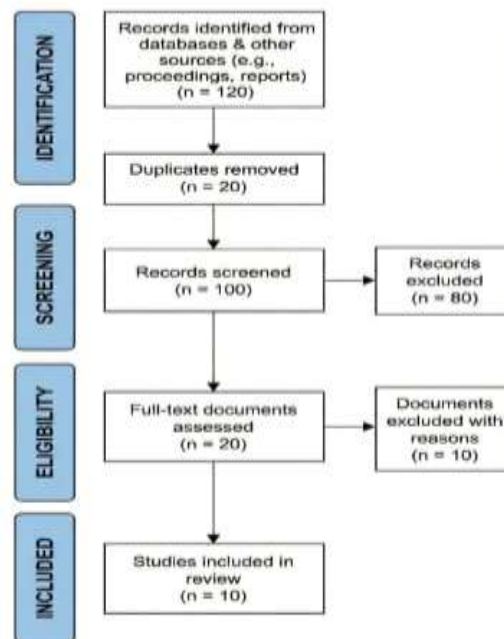


Figure 1. Prisma Diagram Process

RESULT AND DISCUSSION

Selected Article and General Findings

Based on a systematic selection process using the PRISMA protocol, ten ($n=10$) articles were selected that met the eligibility criteria for further analysis. These articles were published between 2011 and 2025, reflecting the evolution of academic discourse on disaster education from initial awareness to specific technical implementation. Geographically, the studies analyzed cover a diverse global representation, ranging from developed country contexts such as the United Kingdom (Thurairajah et al., 2011) and collaborative studies in China (Shimano et al., 2016), to highly disaster-prone developing countries such as Nepal (Adhikari, 2024; Shrestha et al., 2025), Bangladesh (Nipa et al., 2020), and Taiwan (Chu et al., 2018). This diversity of locations indicates that the gap in civil engineering curricula in disaster mitigation is a universal issue that is not limited to specific regions.

Analysis of the study findings reveals that the main challenge in civil engineering education today is not merely a lack of technical material, but rather a systemic failure to integrate field realities into the classroom. Thurairajah et al. (2011) and Shrestha et al. (2025) consistently

highlight the “competency irony,” where built environment undergraduate curricula often neglect the crucial role of disaster management, causing students to rely on social media as their primary source of knowledge instead of formal education. Consequently, as noted by Adhikari (2024) in a case study in Nepal, newly graduated engineers often experience leadership failures in the field due to communication gaps with the community and an inability to use modern risk technologies..

In response to this gap, selected literature offers various pedagogical approaches that have proven to be effective. Nipa et al. (2020) and Krishnan & Liao (2019) emphasize the importance of shifting from passive learning to experiential learning methods, either through hands-on rescue activities or the integration of service-learning where students design actual emergency shelters. This approach is supported by Pimply et al. (2016), who suggest forensic engineering methods, namely post-disaster evaluation-based learning to instill a “learning from failure” mindset.

Furthermore, in terms of curriculum structure, several researchers recommend a more standardized framework. Khorram-Manesh et al. (2016) and Shimano et al. (2016) propose the adoption of global competency standards (such as ISO) adapted to the local context to ensure managerial interoperability. Meanwhile, Chu et al. (2018) offer a practical solution in the form of curriculum stratification, which separates fundamental disaster awareness material (mandatory for all students) from professional engineering material (specific to engineering majors), a strategy that is considered effective in ensuring competency without overburdening an already dense curriculum. These findings, summarized in Table 1, form the basis for the formulation of curriculum integration strategies in Indonesia.

Table 1. Selected Paper to Reviews

Title	Author	Findings	Reccomendation and Action
Incorporate disaster management perspective into built environment undergraduate curriculum	(Thurairajah et al., 2011)	This study highlights that the built environment undergraduate curriculum in the UK still neglects the crucial role of disaster management, even though this competency is urgently needed in the field.	Curriculum Audit: Map existing semester learning plans to insert disaster sub-topics into relevant courses, rather than simply adding new credits.
Disaster Preparedness Education:	(Nipa et al., 2020)	This study reveals that construction students are still vulnerable to disasters due to the lack of integration	K3 & Logistics Integration: Incorporate field simulations or basic SAR training into K3



Construction Curriculum Requirements to Increase Students' Preparedness in Pre- and Post- Disaster Activities		of emergency programs in educational institutions, even though a review of the literature shows that combining theoretical knowledge with hands-on field rescue practices is the most effective strategy for improving their preparedness. However, the implementation of this integrative curriculum is still hampered by major obstacles in the form of a lack of resources and teaching staff trained in disaster mitigation.	Construction courses so that engineers understand the physical conditions in the field after a disaster.
Education in Disaster Management: What Do We Offer and What Do We Need? Proposing a New Global Program	(Khorram-Manesh et al., 2016)	This study highlights that repeated failures in disaster response are often caused by inadequate manager training, leading to the formulation of seven key competency domains that are compiled into a new curriculum with measurable performance indicators for each managerial level. The implementation of this competency-based curriculum is considered effective in improving inter-agency collaboration and maturing the capabilities of disaster managers from the operational to the strategic level through continuing education.	Graduation Standardization: Adopting measurable disaster competency indicators in the Learning Outcomes of Graduates of study programs, not only based on written exam scores.
Assessment of Roles of Engineers for Disaster Management in the Context of Nepal	(Adhikari, 2024)	This case study in Nepal identifies that the main obstacles to engineering leadership in disaster risk reduction are communication gaps with the community and the lack of disaster-related material in the current engineering undergraduate curriculum. Therefore, it is	Modernization of Tools & Communication: Adding Risk Communication material (how to talk to citizens) and the use of AI for risk prediction in elective/compulsory courses.



		recommended that capacity be strengthened through training in advanced technologies (such as machine learning and risk assessment) and intensified cross-sector coordination to close the competency gap in formal education.	
Role of Civil Engineers Pre, During and Post Disasters	(Pimpley et al., 2016)	Although disasters have a destructive impact on civil infrastructure and are impossible to prevent entirely, such events actually reveal flaws in the construction process that can serve as crucial lessons. Therefore, effective mitigation strategies must focus on utilizing post-disaster evaluations to improve the quality of structures and minimize the risk of damage in the future.	Forensic Case Study: Using real data on building failures (e.g., the Cianjur/Palu earthquakes) as mandatory material for structural analysis to instill a mindset of “learning from failure.”
Applications of civil engineering in disaster risk reduction	(Menon et al., 2024)	The implementation of Disaster Risk Reduction (DRR) requires strict compliance with multi-hazard building codes to ensure the operability of critical infrastructure during crises, but this success absolutely requires the integration of DRR material into civil engineering and architecture education curricula. In addition to focusing on new construction, mitigation strategies must include safety audits and retrofitting of vulnerable structures, where findings must be actively communicated to city administrators so that technical standards can be translated into tangible governance policies.	Audit & Advocacy Skills: Training students to conduct “Building Feasibility Audits” (Structural Audits) and how to write technical recommendations that local officials can understand.
Proposal for	(Shimano et	This study highlights the global	International Benchmarking:



Development Cooperation to Enhance the Capacity on Disaster Emergency Response in Developing Countries : A Case Study of Curriculum Development in the People's Republic of China	al., 2016)	imbalance that still favors emergency response over prevention, and responds by developing a tiered earthquake risk management training curriculum for personnel in China through a technical partnership with JICA. By comparing international standards (such as ISO 22320), this study successfully formulated instructional modules that have been verified to be effective in improving personnel capacity, while also proving that the adoption of global standards into local training materials is key to strengthening emergency management systems.	Developing teaching modules that refer to global standards (ISO/Sendai Framework) but with local Indonesian case studies so that graduates are competitive.
Study on disaster prevention education for senior vocational school-A case of civil and architectural group	(Chu et al., 2018)	Faced with the lack of disaster education in Taiwan, this study formulated a two-tier vocational school curriculum structure: fundamental material (science and general safety) that is compulsory for all students, and professional material (engineering design and building regulations) specifically for engineering majors. This stratified model is recommended to ensure the formation of uniform disaster awareness and specific technical competencies without overburdening the existing curriculum structure.	Separation of Material Depth: The material "General Disaster Management" is a general course, while "Earthquake Engineering" is an in-depth specialized course.
Are Disaster-Prone Countries' Undergraduate Students Prepared?	(Shrestha et al., 2025)	A case study of civil engineering students in Nepal reveals the irony that their main source of disaster knowledge comes from social media rather than formal education, which	Project-Based Learning (PjBL): Reduce one-way lectures. Require large design assignments that require students to explicitly apply



Insights From a Civil Engineering Program in Nepal		has resulted in their inability to translate basic resilience concepts into actual structural designs. These findings underscore the urgency of pedagogical reform of the curriculum, given that the lack of formal training has created a serious competency gap where students understand the theory but fail in the technical application of mitigation.	the concept of resilience in their design drawings.
Integrating Shelter Design and Disaster Education in Architectural Curriculum	(Krishnan & Liao, 2019)	This paper proposes a dual approach: the development of modular emergency housing designs that are responsive to various disasters, and the reform of architecture curricula through the integration of service-learning methods and interdisciplinary studios. This educational model is considered effective because it not only trains students' technical competencies in designing deployable structures, but also makes their work a real educational tool for the community in understanding local mitigation strategies.	Thematic Community Service Program/Service Studio: Changing the format of the Community Service Program or Practical Work into a temporary housing (Huntara) design project or earthquake-resistant public facilities in partner villages.

Redefining Engineer Competencies

Literature findings consistently challenge the traditional paradigm that places engineers solely as “structural calculators.” Adhikari (2024) highlights that the biggest obstacle in disaster management is not the inability to calculate earthquake loads, but rather the “communication gap” between engineers and the community and policy makers. Engineers often fail to translate technical risks into language that can trigger public mitigation actions. Therefore, modern curricula are required to include Risk Communication as a core competency, rather than merely a supplement (soft skill).

In line with this, Menon et al. (2024) emphasize the importance of Policy Advocacy



competencies. Future civil engineers must be trained to not only stop at the technical audit stage of buildings, but also be able to formulate policy recommendations that are “executable” by local governments. In addition to communication aspects, literacy in the latest technology is also in the spotlight. The integration of Artificial Intelligence (AI) and Machine Learning-based risk analysis tools into the curriculum is imperative to improve the accuracy of risk predictions, as suggested by Adhikari's (2024) findings, in order to close the technological gap in conventional mitigation practices.

Pedagogical Transformation

Discussions on teaching methods (pedagogy) show that one-way (didactic) lectures have proven ineffective in instilling disaster preparedness. A study by Shrestha et al. (2025) reveals the alarming reality that students rely more on social media than lecture materials for disaster information, which leads to the failure to apply the concept of resilience in design. To overcome this, a radical shift towards active learning is needed. Pimpley et al. (2016) proposed a Forensic Engineering approach, in which students learn directly from post-disaster “structural failures.” This method transforms disasters from mere case studies into evaluation laboratories that instill a critical mindset that every line in a working drawing has life-saving consequences. Furthermore, Nipa et al. (2020) and Krishnan & Liao (2019) proved the effectiveness of field-based learning. The integration of rescue simulations and real-life (1:1) emergency shelter design projects not only improves psychomotor skills but also builds social empathy, which is often absent in conventional engineering education.

Structural Integration Strategies

The biggest challenge in adopting new material is the density of the existing civil engineering curriculum. Adding new courses is often not a realistic option. The strategic solution offered by the literature is through Curriculum Mapping and Stratification. Thurairajah et al. (2011) suggest a comprehensive curriculum audit to identify “entry points” in existing courses—such as inserting emergency logistics material into Project Management courses, or vulnerability audit material into Concrete Structures courses—rather than creating separate courses. Meanwhile, Chu et al. (2018) offer a stratification model that divides the material into two levels: “Disaster Literacy” material that is mandatory for all students as a foundation for a disaster-aware culture, and “Advanced Mitigation Engineering” material for final-year students taking specializations. This approach, combined with the adoption of global competency standards (ISO)



as suggested by Khorram-Manesh et al. (2016) and Shimano et al. (2016), offers a flexible yet standardized framework for bridging the curriculum gap without overburdening students' study load.

CONCLUSION

This study, through a systematic literature review, has successfully mapped the gap analysis between the current civil engineering education curriculum and the reality of disaster mitigation needs in the field. The main findings confirm that the discrepancy in engineers' competencies does not lie in their mathematical calculation abilities (hard engineering), but rather in a deficit of crucial “soft” competencies, including risk communication, policy advocacy, and post-disaster operational readiness. Conventional engineering education in Indonesia appears to be stuck in a rigid technocratic paradigm, producing graduates who understand resilience theory but are at a loss when faced with the social and managerial dynamics of disasters.

FUTURE DIRECTIONS

This study recommends transforming civil engineering higher education through three main integration strategies. First, from a pedagogical perspective, a radical shift is needed from passive didactic methods to experiential learning that includes Forensic Engineering (learning from structural failures) and Service-Learning (real humanitarian projects). Second, in terms of competencies, the curriculum must explicitly include modern technological literacy (such as AI for risk prediction) and public communication skills as mandatory learning outcomes. Third, structurally, study programs are advised to conduct curriculum mapping and stratify material to incorporate disaster content without overburdening students. Practical implications of this research urge engineering education institutions in Indonesia to immediately conduct curriculum audits and adopt global disaster competency standards adapted to the local context. Future engineers should no longer be seen merely as designers of concrete and steel, but as key agents of public safety with social empathy and managerial acumen.

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