

Improving Competence in the Seismic Code Implementation for Housing in Indonesia using Visualization and Practical Exercises

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Abstract. Recent data on earthquake tragedies reveals that the seismic code implementation for residential houses is remarkably rare in Indonesia. Improvement of construction actors' competence for this situation is important. This paper examined the application of video-based visualization and practical exercises as educational tools for seismic code application to improve the competence of construction actors in the context of non-engineered residential houses in Indonesia. Video-based visualizations were compiled from several social media sources, and practical exercise materials were developed utilizing different essential aspects of quality building materials. There were 19 masons and carpenters involved in this study through a focus group discussion to evaluate the improvement of competencies before and after seeing the video and participating in practical exercises in the Bantul District, Indonesia. The results have demonstrated an enhancement in competence of around 29.01% among participants before and after seeing the video and participating in practice. A significant correlation ($r=0.602$) was observed between the participants' educational background and their improvement in the application of seismic codes. The age group of 42-43 years has had the most significant enhancement in competency compared to others. Work experience and age show no significant correlation ($r=0.129$ and $r=-0.216$ respectively) with the increase of competence.

1 Introduction

Historically, the impact of earthquakes has resulted in horrific disasters globally, regarded as one of nature's most terrifying and devastating phenomena. According to the Indonesian Seismic Zonation, about 60% of cities and urban centers in Indonesia, around 290 out of 481, are situated in regions classified as reasonably high to very high seismic zones [1]. The earthquake in Yogyakarta, Indonesia, on May 27, 2006, resulted in around 6,000 fatalities and the destruction of over 155,000 houses. The earthquakes in Palu and Cianjur, Indonesia, in 2018 and 2022 caused the serious destruction or collapse of 20,129 and 21,465 houses, respectively [2, 3]. These earthquakes underscore the widespread vulnerability of Indonesian

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housing due to insufficient earthquake-resistant construction. The majority of the collapsed or severely damaged structures were non-engineered masonry buildings, composed of heavy materials, with or without reinforced concrete structures, particularly those owned by medium-low-income communities or as low-cost housing [4].

As traditional wooden buildings are hard to find and expensive, most homes in Indonesia are non-engineered structures, primarily consisting of heavy materials such as half-brick thick masonry strengthened with reinforced concrete frameworks. These constructions, referred to as "practical columns and beams," are often labelled as 'a new culture' [5], as noted by Boen. Moreover, many Indonesians have started to apply these "new culture" structures to raise their social status and cut down on maintenance costs. At the same time, these "new culture" buildings are often constructed without considering seismic performance, turning buildings into death traps. Boen has emphasized that if these "new culture" non-engineered houses are constructed using high-quality materials and competent workmanship, they are likely to withstand the most severe earthquakes predicted by the Indonesian seismic hazard map.

Characteristics of non-engineered structures have ignored basic earthquake-safety principles mentioned in Indonesian seismic codes (especially SNI 1726:2019) like confinement of masonry, ductile detailing of reinforcement, and continuous load path. Subsequent seismic incidents in Indonesia have revealed that most newly constructed cultural homes lack adequate earthquake resilience, with just a small number built according to recommended seismic resistance standards. While some reconstruction efforts aimed at providing safer housing, many homes still showed discrepancies with local characteristics and did not fully address principles of earthquake-resilient construction [6]. Although some homeowners have adopted reinforced concrete frames for added strength, many modifications have not been aligned with proper seismic-resistant building principles [7]. Numerous deficiencies in construction management include lack of detail in design and planning, absence of building permits, and failure to adhere to technical specifications for earthquake resilience. Despite ongoing efforts to improve post-earthquake reconstruction and promote earthquake-resilient housing in Indonesia, significant gaps remain in aligning local construction practices with seismic-resistance standards [8]. In particular, there is limited emphasis on systematic training and capacity building for grassroots construction actors - such as masons and carpenters - who are central to the delivery of non-engineered housing. This gap highlights the urgent need for approaches that not only strengthen technical competencies in seismic-safe construction but also preserve local cultural traditions in housing design.

Research undertaken prior to the Yogyakarta earthquake indicated that 93.5% of residential housing in Yogyakarta City included non-engineered constructions [9] in which 84.8% of non-engineered houses were constructed from heavy materials, specifically masonry buildings with one or half brick thickness. Among these, 1% were extremely traditional houses without reinforcement and adequate maintenance, while 83.8% represented what appeared to be 'the new culture' housing. There were 8.7% of houses constructed using lightweight materials, including teakwood in traditional and historic structures and were non-engineered. Some of them were among the poorest of the poor, constructed with extremely lightweight materials that may withstand significant seismic activity and are less deadly in the event of a collapse. The last category comprised just 6.5% of the engineered houses, which were ultimately owned by wealthy people.

The issue of sociocultural dynamics has become increasingly prominent during the implementation of seismic measures in non-engineered houses, which involve more than just physical intervention, since this construction practice is frequently influenced by local wisdom of social cohesion and community spirit. Small to medium-sized contractors, foremen, masons, and carpenters are the primary actors in non-engineered building processes,

typically employing vernacular methods, local resources, and labor-intensive techniques, often relying on unwritten rules and without official contracts or arrangements. In certain instances, homeowners may have complete control over the whole construction process, leaving contractors with no bargaining power to propose alternative methods, if applicable. They all frequently possess inferior education, inadequate training, limited access to knowledge, and less attention from modern science and technology. They acquire building skills organically via hands-on experience and observation of local practices. Ultimately, they are the primary factors in the implementation of seismic elements in the building of non-engineered structures. Consequently, it is essential to reconcile the gaps between knowledge and action to prevent the generation of new risks by permanently altering building practices in accordance with traditional cultural knowledge and local social cohesiveness. An exemplary training-based intervention has been conducted in Pacitan, Java Island, Indonesia, targeting construction workers (contractors, foremen, masons) to enhance their competence and understanding of earthquake catastrophe preparedness [10]. However, there remains a critical research gap in systematically measuring the extent of knowledge improvement or increment gained through such training and capacity-building programs for grassroots construction actors in the context of non-engineered housing.

The role and challenges of social media and visual tools have emerged following a workshop on 'seismic risk management of non-engineered housings' held in 2006 in Yogyakarta [9] that seismic codes must be articulated in simple language that is socially and culturally acceptable, easily implementable, and cost-effective. Effective information transmission and knowledge transfer among construction actors is recognized as the primary approach to address poor communication [11], hence enhancing the effective utilization of resources within the non-engineered construction sector. Also, grass root construction actors exhibit a preference for visual content over written material in the dissemination of these codes. Due to the visual content, social media, through visual information, offers a range of interactive modules, educational videos as a dynamic distribution method, and learning materials that are readily accessible to the general audience, enabling anyone to independently learn how to integrate seismic characteristics. The utilization of visual information via social media has the potential to enhance public education for evaluating community resilience [12]. Similarly, this can complement and improve current knowledge of seismic code implementation associated with disaster preventive strategies. This has been recognized as a valuable means of distributing information and offering guidance to the public [13, 14]. In addition, inferior building materials typically contribute to the collapse of housings during earthquakes [5]. Consequently, visualization aimed at enhancing the competence of construction actors must incorporate both simple video-based visualizations sourced from various social media platforms and practical exercises focused on identifying quality building materials. Materials such as river sand, gravel, cement, steel bars, bricks, and lightweight concrete blocks need to be tested visually to distinguish which materials are either good or bad.

Despite the constantly evolving nature of social media, there is a lack of systematic research regarding its impact on the knowledge improvement of construction actors. This paper aims to assess the improvement of knowledge or competency regarding seismic characteristics among construction actors in the context of non-engineered housing, comparing the period before and after watching the video-based visualizations and the visual evaluation of quality materials through a focus group discussion.

2 Research Methodology

2.1 Focus Group Discussion

A house in Trirenggo Village, Bantul District area, Special Province of Yogyakarta that survived the 2006 earthquake was chosen as the site of the focus group discussion (FGD), presenting about how seismic-resistant homes can be used as a practical classroom, motivational symbol, and community proof-of-concept. This helps the FGD participants learn more about the topic and become more emotionally committed to it. The selection of the survived house, indeed, facilitated sense of place and sense of control to the FGD's mind. Nineteen local construction practitioners, including masons and carpenters through a purposive sampling, participated in the FGD. Before participation, ethical approval was secured, and informed consent was acquired from all participants by the signing of a letter of agreement during the session. Innovative initiatives and new synergies were easily absorbed over this process. These were easily integrated into the preexisting community structures and recognized the importance of each individual's participation. They were categorized into their educational background, work experiences, and ages, as mentioned later in Table 2.

The videos used for learning visual media come from various social media platforms, such as Facebook, TikTok, and Instagram. This visualization included site, design, seismic features, good construction materials, and other characteristics. Figure 1 and 2 presents examples of anchor for tie beam and steel bar arrangements. Participants in the FGD were presented with locally obtained samples of high-quality and substandard materials, including river sand, gravel, cement, steel bars, and bricks, for comparative analysis in determining the best material. The Indonesian standard (SNI 2847-2019) was utilized as benchmark while assessing the quality of the material. The presentation of those several construction materials was provided both via visualized videos and actual samples.

During the FGD, the participants examined their level of competence both before and after watching the developed visualization through a previously piloted questionnaire. The definition of competence was the demonstrated ability among masons and carpenters to apply knowledge (understanding seismic risks), skills (evaluating material quality), and attitudes (awareness of earthquake-resistant construction importance) to perform tasks effectively in the application of seismic features in common houses. Assessment has been aligned with Indonesian National Work Competency Standards for construction workers. A questionnaire pilot test was conducted via a focused discussion with four personnel from the Bantul District Disaster Office. The participants were purposively selected based on their significant involvement in disaster training programs for general masons and carpenters, ensuring that their experience was relevant to the study context. The draft questionnaire was systematically reviewed during the session to evaluate the clarity, relevance, and comprehensiveness of each item, with particular attention to the relevance of wording, terminology, and sequencing. Feedback obtained from the discussion was carefully documented and utilized to refine the instrument, thereby strengthening its content and construct validity, in addition to its practical applicability. The final version of the updated questionnaire was then made ready for use in the next round of data collecting.

Furthermore, participants were tested to distinguish which materials were either good or bad both before and after watching the visualization and evaluating the actual material samples. Specifically for measuring the quality of concrete block material, there was a drop test on light weight concrete block on hard soil (Figure 3) and if there was no broken block after the test, this concrete block was an acceptable quality. Their competence improvement was elaborated further, and a correlation between the competence improvement and participants' characteristic was then analyzed. SPSS program was used in this computation.

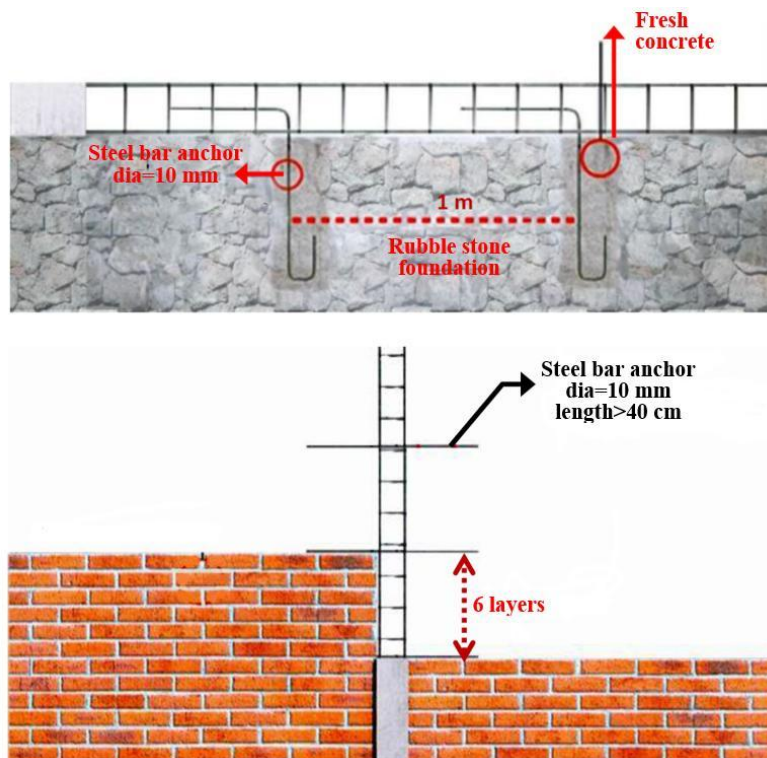


Fig. 1. Examples of the video contents: anchor for tie beam and wall (edited from Permen PUPR No. 5/PRT/M/2016).

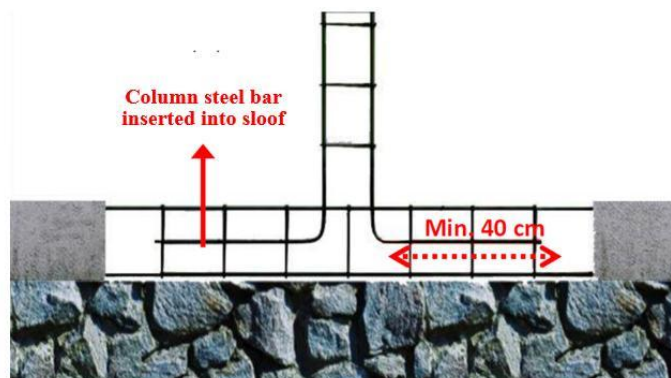


Fig. 2. Examples of the video contents: steel reinforced connection at bottom (edited from Permen PUPR No. 5/PRT/M/2016).

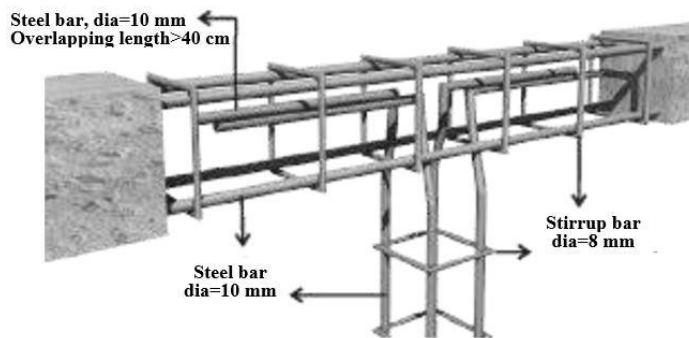


Fig. 3. Examples of the video contents: steel reinforced connection at top (edited from Permen PUPR No. 5/PRT/M/2016).

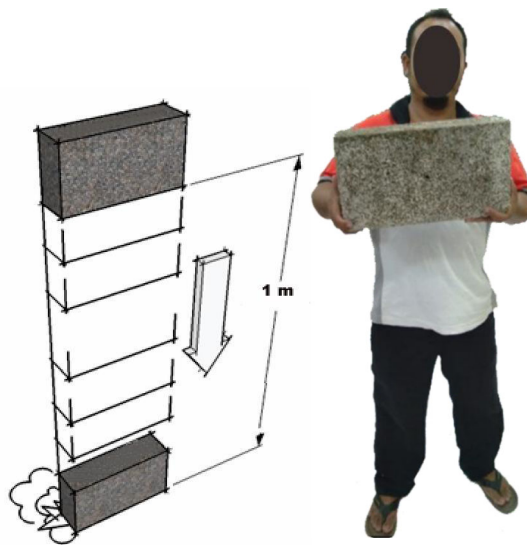


Fig. 4. Drop test on light weight concrete block.

2.2 Correlation Coefficients

The correlation coefficient is used to find how strong a relationship is between two variables. There are different types of correlation values, but Pearson's is the most popular. A correlation measure that is often used in linear regression is Pearson correlation, which is also written as Pearson's R. The methods give back a number between -1 and 1. A value of 1 means there is a strong positive relationship, a value of -1 means there is a strong negative relationship, and a value of 0 means there is no relationship at all. There is a critical value from a table (taken Pearson's Correlation Table) for two-tails tests. If the calculated Pearson's correlation coefficient is greater than the critical value from the table, then the relationship is statistically significant.

2.3 Questionnaires

A piloted questionnaire was administered to assess participants' competence both prior to and following exposure to instructional videos and practical exercises. The instrument focused on evaluating knowledge related to the implementation of seismic codes in residential housing, with its content developed based on established literature [9]. As shown in Table 1, the questionnaire comprises 12 items designed to measure respondents' understanding of seismic code application in residential buildings, with each correct response awarded a score of 4.

Table 1. Twelve question indicators for a good implementation of seismic features [9].

Criteria	Question indicators	Optional answers with a randomly selected correct answer
Steel reinforcement	1. Good steel reinforcement detail: stirrup spacing <15 cm	(1) stirrup spacing > 20 cm; (2) stirrup spacing 15-20 cm; (3) stirrup spacing <15 cm; (4) stirrup spacing <15 cm and hook 135°
	2. Good steel reinforcement detail: beam-column connection	(1) lapping longitudinal > 40 cm; (2) lapping longitudinal 30-40 cm; (3) lapping longitudinal 20-30 cm; (4) lapping longitudinal 10-20 cm
Lateral load path	3. Existence of lateral load path: plinth band	(1) plinth band; (2) brick layered band
	4. Existence of lateral load path: vertical reinforcement in all wall corners	(1) concrete practical column; (2) wood column; (3) bamboo concrete column
	5. Existence of lateral load path: roof-gable band	(1) roof band; (2) simple anchors to roof structure
	6. Existence of lateral load path: lintel band	(1) lintel band; (2) brick band
Anchors	7. Existence of foundation anchors to wall and wall anchors to vertical reinforcement	(1) foundation anchors; (2) wall anchors; (3) foundation and wall anchors
Building material	8. Good quality of cement	(1) grey colors; (2) loose material; (3) lump cement
	9. Good quality of sand and gravel	(1) dirty sand-gravel; (2) homogenous size of sand-gravel; (3) coarse sand; (4) solid gravel; (5) heavy gravel
	10. Good quality of steel reinforcement	(1) dirty steel; (2) new steel; (3) used steel; (4) diameter >10 mm
	11. Good quality of concrete block	(1) fragile concrete block; (3) lightweight material; (3) heavy material; (4) strong material
Workmanship	12. Good quality of workmanship	(1) junior mason; (2) senior mason; (3) agile mason; (4) high productivity mason

3 Results and discussion

A Focus Group Discussion (FGD) with 19 participants from the house construction sector was held. FGD participants were classified into three categories: academic background, age, and job experience. Participants were first briefed on the aim and objectives of the FGD, followed by a pre-test administered via a questionnaire assessing their current knowledge on the implementation of earthquake-resistant housing practices they have undertaken thus far. A visualization video and practical exercise demonstrating effective procedures in the

execution of earthquake-resistant building requirements were then presented to enhance their understanding. Subsequent to watching visualization and practical activity, participants were requested to complete an identical questionnaire to assess the extent of their enhanced comprehension and knowledge. Table 2 presents the test scores of FGD participants before to (pre-test) and subsequent to (post-test) viewing the visualization and engaging in practice.

Table 2. The test scores of FGD participants: pre-test and post-test.

Participant number	Ages	Educational background	Work experiences, years	Pre-test score*	Post-test score *	Knowledge Increment
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(6)-(5)
#1	32	High school (SMA)	15	21	28	7
#2	41	High school (SMA)	2	24	30	6
Average						6.5
#3	42	Secondary school (SMP)	25	16	25	9
#4	53	Secondary school (SMP)	35	22	28	6
#5	56	Secondary school (SMP)	20	16	20	4
#6	56	Secondary school (SMP)	35	15	22	7
#7	57	Secondary school (SMP)	40	19	24	5
Average						6.2
#8	43	Elementary school (SD)	23	15	23	8
#9	38	Elementary school (SD)	18	15	20	5
#10	48	Elementary school (SD)	25	14	17	3
#11	49	Elementary school (SD)	25	18	21	3
#12	50	Elementary school (SD)	33	16	23	7
#13	50	Elementary school (SD)	29	17	22	5
#14	53	Elementary school (SD)	11	17	20	3
#15	53	Elementary school (SD)	32	23	25	2
#16	60	Elementary school (SD)	40	16	21	5
#17	66	Elementary school (SD)	50	21	24	3
Average						4.4
#18	50	Incomplete elementary school (<SD)	27	12	15	3
#19	43	Incomplete elementary school (<SD)	22	7	10	3
Average						3
Average				17.05	22	4.94
Percentage of knowledge increment						29.01%

*) Maximum score is 48

Table 2 indicates that grassroots construction actors in the context of non-engineered residential houses in Indonesia may enhance their understanding of implementing seismic elements in buildings through dynamic visualization and practical use as an effective tool. Similar findings have revealed that the educational intervention effectively enhanced participants' knowledge and practices about earthquake preparedness [13]. Other study has presented on how education level affects competence of construction workers in Indonesia [14].

The maximum knowledge increment score is 6.5 for the FGD participant possessing a high school (SMA/SMK) educational background. Conversely, the minimum increment is 3 for respondents with an educational background of incomplete primary school (<SD). The knowledge improvement among respondents with educational backgrounds of SD and SMP is 4.4 and 6.2, respectively. The mean enhancement of competence or knowledge before and after viewing and practicing the visualization is 29.01%. Similar study provided 33% of knowledge increments [10]. The respondents aged approximately 42-43 have demonstrated the most substantial increase in their knowledge or competence.

These findings indicate that visualization-based training can effectively enhance knowledge across diverse educational backgrounds, with greater improvement observed among participants with higher baseline education levels, aligning with previous research highlighting the role of education in facilitating knowledge acquisition [15]. Moreover, higher levels of prior education significantly provide a foundational understanding and better cognitive abilities for learning, though programs must be tailored to participants' existing knowledge and context to ensure efficacy. Participants with more formal education may find it easier to process new information and apply it in practical contexts, while less-educated participants may require more support and context-specific guidance for effective learning transfer.

According to Table 2, Figure 5 illustrates the characteristics of FGD participants about their educational background and the increase in knowledge seen between the pre-test and post-test.

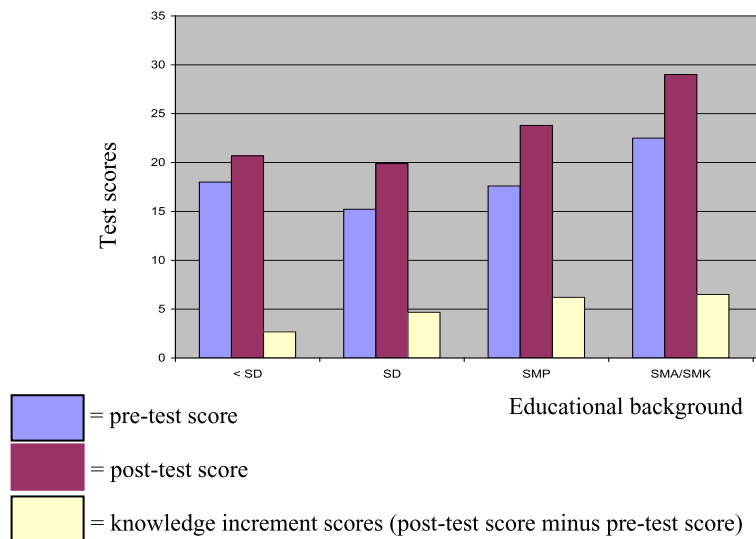


Fig. 5. The histogram of the educational background, test scores, and knowledge gains of FGD participants

A correlation between educational background and knowledge enhancement is arranged to supplement the aforementioned conclusion. The correlation coefficient (r_{result}) is 0.602, whereas the critical value (r_{table}) is 0.456 at a 95% significance level. This result indicates that the correlation is beyond the critical threshold, signifying a positive significant association between educational background and knowledge enhancement. The relationship between work experience, age, and knowledge enhancement is not statistically significant. These indicate a result of $r = 0.129$ for work experience and $r = -0.216$ for ages below the crucial value, with $r_{\text{table}} = 0.456$. Figure 6 illustrates the comprehensive correlation results.

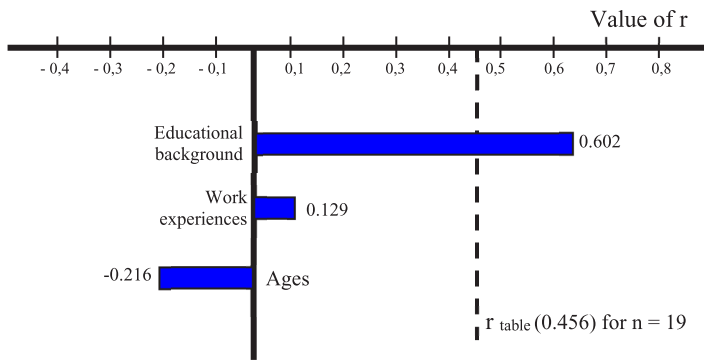


Fig. 6. The correlation between educational background, work experience, age, and enhancement of knowledge.

This study demonstrates that the learning strategy for grassroots construction actors using dynamic visualization and practical exercises has had positive outcomes. This study analyzed the changes in knowledge among 19 respondents from house construction sectors before and after viewing and practicing a dynamic visualization of seismic code execution in residential structures. Table 2 presents that all respondents clearly indicated an enhancement in their knowledge after viewing and practicing the visualization, however the degree of knowledge change varied among them. Three attributes - educational background, age, and job experience - have been analyzed for their link with the knowledge changes of respondents before and after viewing and practicing the visualization. The results indicate a robust positive correlation of 0.602 between educational background and knowledge growth. An enhancement in educational background signifies an augmentation in the worth of knowledge.

This study clearly indicates that dynamic visualization is essential for construction professionals to enhance their understanding. Moreover, higher education enhances knowledge acquisition more effectively. Construction actors engaged in the frontline of projects must get rigorous training to ensure the effective implementation of seismic codes, hence facilitating the development of more earthquake-resistant structures universally. The government, responsible for public safety against seismic events, must communicate the advantages of dynamic visualization to all stakeholders in construction. A multitude of parties should be convened and consolidated to undertake and share this effort and responsibility.

4 Conclusions

This study has successfully evaluated the improvement of knowledge and competency regarding seismic characteristics among construction actors in the context of non-engineered housing. By comparing the period before and after video-based visualization and the visual evaluation of quality materials through a focus group discussion, it was revealed that construction actors can substantially enhance their understanding of implementing seismic features in buildings. The mean improvement of 29.01% demonstrates the effectiveness of visualization-based training as an educational tool. Moreover, knowledge enhancement was obvious across different educational backgrounds, with participants of higher baseline education showing greater improvement, as provided in the moderate correlation ($r = 0.602$). In contrast, age and work experience showed no significant correlation with knowledge increment, suggesting that structured learning interventions may play a more critical role than experiential learning alone in improving earthquake-resilient construction practices.

However, these findings should be interpreted with caution due to certain limitations. The participants in this study were exclusively from Trirenggo Village, which may not represent the diversity of grassroots construction actors across Indonesia. Future research should therefore broaden the scope to encompass various regions, cultural contexts, and construction practices. Additionally, while video materials on seismic features are widely available through various social media platforms, their quality, content, and focus are not always the same. To build a stronger culture of prevention, there is a need for systematic effort of standardized training videos supported by government incentives, policies, and institutional discretion. Such an approach would not only strengthen training and capacity building among grassroots construction actors but also combine local traditions with seismic-resilience standards to reduce long-term housing vulnerability in Indonesia.

Acknowledgements. Some works contributed to this paper were funded by DPPM UII based on Contract No: 002/Dir/DPPM/70/Pen.PengembanganInstitusi/IV/2025. The authors express gratitude to the management of the Faculty of Civil Engineering and Planning at Universitas Islam Indonesia for providing the research facilities for this work. In particular, the author would like to thank many technicians in the Innovation Center of UII during the production of video and materials.

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