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Factors Influencing Classroom Acoustic Design in North Sumatra: Bahasa Indonesia as the Language of Instruction

Faktor-faktor yang Mempengaruhi Desain Akustik Ruang Kelas di Sumatera Utara: Bahasa Indonesia sebagai Bahasa Pengantar Pengajaran

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Abstract

Classrooms with optimal acoustic design can directly improve students' listening. Studies have shown that providing a good communication environment for classroom instructors is crucial for students to achieve good grades. Some students who receive poor grades find it difficult to concentrate when speech intelligibility is inadequate or because of excessive noise. However, these studies are based on English as the teaching medium. Indonesia is a developing country with a global population ranking number 4. The Indonesian Ministry of Education anticipates more educational facilities to be built under its mission to realize relevant education of high quality, equitable and sustainable, supported by infrastructure and technology. Will education with Indonesian as the primary language also follow the classroom architecture and acoustics design element? Thus, this study aims to explore views from the relevant important classroom architecture and acoustics design elements. Classroom facilities can support the educating and instructing process. Acoustic factors in the classroom can affect students' and instructors' concentration and comfort. A questionnaire was distributed among Indonesian respondents who work as acoustic engineers, architects, and educators to gain their views about classroom acoustics design factors. Thirty individuals responded to the questionnaire – ten persons in each group. The importance of the acoustics design aspects from each occupation group was measured through statistical analysis of questionnaire results. According to acoustic engineers, Reverberation Times and Sound Insulation are essential to designing classroom acoustics. The architect group assessed Reverberation Times as a less important aspect. However, according to architects and educators, Speech Intelligibility is regarded as the most crucial factor in an Indonesian-language classroom. In short, an evaluation of Indonesian classroom architectural and acoustics features are conducted to make improvements. The school education board, architects, and acoustic engineers could use the results to make better design decisions.

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Keywords

classroom acoustics, Indonesian, reverberation time, sound insulation, speech intelligibility

Abstrak

Desain akustik yang optimal dalam ruang kelas dapat secara langsung berkontribusi pada peningkatan kemampuan siswa. Studi menunjukkan bahwa penyediaan lingkungan kelas yang optimal memiliki dampak signifikan terhadap pencapaian nilai siswa. Sejumlah siswa mengalami penurunan nilai akibat kesulitan dalam berkonsentrasi, yang disebabkan oleh kurangnya kejelasan dalam mendengar atau adanya gangguan kebisingan.Kementerian Pendidikan Indonesia merencanakan lebih banyak pembangunan fasilitas pendidikan sebagai bagian dari misinya untuk menciptakan pendidikan yang berkualitas tinggi, merata, dan berkelanjutan akan tetapi standar akustik yang berlaku saat ini mengikuti pedoman yang ditetapkan dalam bahasa Inggris. Apakah pendidikan yang menggunakan bahasa Indonesia sebagai bahasa utama akan mempertimbangkan elemen desain arsitektur dan akustik kelas yang diterapkan dalam bahasa Inggris? Studi ini bertujuan untuk menganalisis perspektif arsitektur dan akustik terkait desain akustik yang diterapkan di dalam ruang kelas. Faktor akustik di kelas memiliki dampak signifikan terhadap konsentrasi dan kenyamanan baik siswa maupun guru. Kuesioner telah disebarkan kepada responden di Indonesia yang berprofesi sebagai insinyur akustik, arsitek, dan pendidik untuk mengumpulkan pandangan mereka mengenai faktor-faktor yang mempengaruhi desain akustik di kelas. Tiga puluh individu memberikan respons terhadap kuesioner tersebut, dengan sepuluh orang dari masing-masing kelompok. Aspek desain akustik dari setiap kelompok pekerjaan diukur dengan menggunakan analisis statistik hasil kuesioner, yang menunjukkan signifikansi dan relevansi data yang diperoleh. Secara ringkas, analisis terhadap fitur arsitektur dan akustik kelas di Indonesia dilakukan untuk tujuan perbaikan. Hasil tersebut dapat dimanfaatkan oleh dewan pendidikan sekolah, arsitek, dan insinyur akustik untuk meningkatkan kualitas keputusan desain yang diambil.

Kata Kunci

akustik kelas, Bahasa Indonesia, isolasi suara, kejelasan ucapan, waktu reverberasi.

INTRODUCTION

The number of schools in the country has increased over the years as the Indonesian government has made a concerted effort to improve access to education, especially in rural and remote areas. The government has built new schools, expanded existing ones, and provided more funding for education to address the needs of the rapidly growing population. However, the awareness of providing a comfortable environment in terms of acoustic and thermal effects is lower in Indonesia (Rabiyantia et al., 2017). This condition is inversely

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proportional to the mission of the Indonesian Ministry of Education and Culture to support the infrastructure and technology of the education system in Indonesia.

Education and developing a child's life at each growth stage are essential. Students in Indonesia must be helped to prepare for a meaningful transition toward independent adult life(Hasbullah et al., 2011). Compared to other sectors, such as healthcare, social services, law enforcement, and municipal governments, the literature on the application of school performance still needs to be more extensive in the educational setting (Sarrico et al., 2004) . The educational facilities' level of sophistication impacts the learning environment's quality. Factors to consider about facilities, including the facility's age, the thermal environment, the ventilation, and acoustics, affect the adequacy of the learning environment (Morris, 2003).

The school influences and moulds the education of humans' identity individually and collectively. The school symbolizes achieving the education system's goals (Proshansky et al., 1983). The acoustics design of the classroom must help the student catch the information at least 90% of what the instructor conveys in the room (Gheller et al., 2019). According to Choi and McPherson (2005), since that instructors have to talk for long periods, acoustics design plays a role in helping instructors deliver the words without causing any health problems. Words are the basic unit of language; every word the instructor communicates in the classroom is composed of consonants and vowels, each of which contributes a unique level of clarity to the word and how vowels are articulated from one language to another (Bradlow, 1995). Variations in pronunciation influence the speech intelligibility of instructors.

The school facilities are widely recognized as an essential component in playing a supporting role in providing exemplary service in the environment for teaching and learning. However, several things need to be improved in the acoustics design performance, such as preliminary investigations of the performance of school facilities, which still need to be done in Indonesia (Hasbullah et al., 2011). Therefore, considering Indonesian as the primary teaching language, this research aims to explore the views of acoustic engineers, architects, and educators on important classroom architectural and acoustic design elements that can influence the teaching and learning process in Indonesian classrooms.

ARCHITECTURE FACTORS

A student's ability to concentrate, the amount of information they can remember, and their general comfort level can all be directly influenced by the quality of the acoustics in the classroom (Choi et al., 2013). Therefore, poor acoustic design in the school classroom could harm the learning environment for the instruction process and the students (Dockrell & Shield, 2006). According to Earthman (2004) classroom acoustics design could be considered the characteristics of the classroom to gain the connection between acoustic conditions and the academic achievement of students. Such as if there is a lot of background noise and if there are different kinds of indoor finishing materials (like hard and soft flooring).

In the classroom for younger children, students have a diminished capacity to pay attention even when other activities coincide (Napoli et al., 2008). It stands to reason that students' and instructors' conversations yield better results for learning when both parties can easily hear themselves and when outside influences can be easily distinguished from one another. The results of studies looking at the acoustics in classrooms next to noisy traffic and community noise have shown that student performance in these classrooms is lower when compared to classroom settings located in residential or classrooms equipped with omission interventions (Earthman, 2004). The classroom's location in the city centre and acoustic standards that fail to correlate to the language of instruction used in the class can make it difficult for students to concentrate. Noise controls such as using rubber floor mats, soundproof tiles, and other noise control treatments in the classroom are standard.

ACOUSTIC FACTORS

According to the World Health Organization (WHO) and the International Labor Organization, sound between 0 and 30 dB is unpleasant. Therefore, WHO recommends a maximum noise level of 55 dB in the classroom. The ANSI S12.60 standard for Classroom Acoustics covers reverberation time, background noise, and speech intelligibility. T30 Reverberation Time or the maximum reverberation time in an empty, furnished classroom with a volume below 10,000 cubic feet is 0.6 seconds, and 0.7 seconds for classrooms between 10,000 and 20,000 cubic feet (Bistafa & Bradley, 2000).High reverberation times will cause a buildup of noise levels in a space. The effect of reverberation time on a given area is critical for musical conditions and speech comprehension. In addition, different functions of the room require other reverberation times.

STI is a crucial acoustic parameter for speech clarity (Bradley, 1986). According to Goldsworthy and Greenberg (2004) speech intelligence requires evaluating acoustic descriptors to determine whether hearing correction interventions should be performed. Measurement and evaluation techniques are described in ISO 3382 for C50 and T30 and IEC

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EN 60268-16 for SI. A C50 value is 6 dB or higher (125-4000 Hz), and instructors and students seem satisfied with the acoustic classroom environment (ISO 3382-2.2008). According to previous research conducted in the laboratory, the types of acoustic disturbances affect students' ability to recognize speech (Russo & Ruggiero, 2019). Three important resonances occur below 3500 Hz in the human vocal tract (Titze, 2001).

Moreover, analysis of different vowels can help differentiate between speakers even when they use the same vowel in their pronunciation (Harrington et al., 2000). The format value contains a large amount of information about the speaker. For example, the low-pitched voice typical of bass singers in Russia is only occasionally heard in other countries. Due to a confluence of factors, some of which are general shape, certain anatomical features, cultural heritage, and environmental influences. In addition, acoustic measurements found that factors such as ethnicity, gender, and spoken language influence Speech Intelligence (Dada et al., 2021). Variation in Speech Intelligence is the root cause of the differences found in acoustic measurements (Schiavetti, 1992).

Reverberation Time and Speech Intelligence significantly increase students' attention to what the instructor says in class (Garcia et al., 2014). Therefore, Reverberation Time and Speech Intelligence are equally essential and interrelated (Shams & Ramakrishnan, 2012). Furthermore, reverberation Time is the factor that has received the most attention in the research literature and is also the most frequently cited acoustic measurement parameter (Mikulski & Radosz, 2011). Therefore, the relationship between Reverberation Time and Speech Intelligence cannot be ignored. Although increased Reverberation Time can make it more difficult to understand speech, it is crucial to be at the best possible level for the instructor's words to be understood by students (Shams & Ramakrishnan, 2012).

Classrooms with poor acoustics can cause hearing loss and misinterpretation of speech for children. Understanding what is being said in a classroom setting can be challenging due to acoustic factors, such as background noise, reverberation time, and physical distance between speaker and listener (Crandell & Smaldino, 2000). A bad acoustic environment is also associated with decreased academic performance, so students who miss essential words, phrases, and ideas in class will experience a considerable loss (James et al., 2012). Several studies and institutions, such as the World Health Organization and the European Commission, have concluded that education is essential in increasing mental clarity. In addition, informal education is associated with better levels of well-being in activity-focused research projects (Jenkins & Mostafa, 2015). However, growing evidence suggests that environments with excessive background noise may not be optimal for learning, even when many schools are crowded.

METHODS

Research Questioner

This study is guided by what are the most important architectural and acoustic design elements for classrooms in North Sumatra, where Bahasa Indonesia serves as the main language, as perceived by professionals in the fields of acoustic engineering, architecture, and education. The question aims to capture the intersection of design context, architectural practice, and acoustic performance, focusing on expert perspectives to identify the design factors most relevant to enhancing teaching and learning outcomes in Indonesian-language classrooms.

Case Study

The case study focuses on classrooms in North Sumatra, Indonesia, a region with diverse school building designs, varying construction quality, and a mix of urban and rural educational facilities. North Sumatra was selected for three primary reasons:

1. Design context (interior) – The region exhibits a wide range of classroom interior configurations, including differences in layout, finishes, ceiling heights, wall treatments, and furniture arrangements, providing an opportunity to assess how interior design elements influence acoustic performance.
2. Diverse building typologies – The area includes educational facilities constructed using different structural systems and materials, offering varied architectural characteristics and acoustic behaviors.
3. Relevance to national educational goals – As part of the Indonesian Ministry of Education's infrastructure expansion program, many schools in North Sumatra are undergoing new construction or renovation, making the findings applicable to current and future classroom design projects.

Observation and Data Collection

Thirty participants in this study were chosen for participation based on their professional affiliation with the acoustic design of the classroom, as shown in Table 1. Those who took the time to complete the questionnaire had an average of ten years of professional experience.

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Acoustic engineers, architects, and educators are the three groups of professionals who contribute their understanding of which factors are the most significant when planning the acoustics of classrooms for this study.

Table 1. Participant's Background

Group			Gender		Experience	
Acoustic Engineering	Architect	Educator	M	F	5-10 years	> 10 years
33.30%	33.30%	33.30%	71%	29%	60%	40%

Source: Siregar, 2025

The research data was obtained by dividing the process into three steps. In the first step, acoustic engineers, architects, and educators were asked to identify the most significant factors in the acoustic design of classrooms in Indonesia. Each participant gives at least five answers; the factors stated here are combined and sorted; factors with the same meaning are eliminated and included into one factor. This first step produced 16 factors for further examination.

In the second step, the experts were asked to rate the 16 factors obtained from the first step. The quantitative measurements were acquired from the Likert-scale ratings. The factors affecting acoustics design were assessed on the following questionnaire in order of Not Important, Slightly Important, Important, Fairly Important, and Very Important. The rating levels were converted into numbers: Not Important = 1, Slightly Important = 2, Important = 3, Fairly Important = 4, and Very Important = 5. The user's preference for each of the eight-factor assessment criteria is shown in Table 2. Factors values below three are eliminated, and eight factors have been produced for the assessment based on the responses received. The eight elements are Window and Door, Room Shape, Surface Material, Classroom Layout, Sound Intensity, Reverberation Times, Speech intelligibility, and Sound Insulation.

Table 2. Evaluation Matrix and Classification

Matrix	Classification	Reference
Window and Door	Quantities of window and doors	(Hongisto et al., 2022; Hopkins, 2003)
Room Shape	Classroom height and length	(Kolarik et al., 2020; Shield et al., 2015)
Surface Material	Classroom supplies (walls, floors, ceilings, furniture, etc.)	(Guardino & Antia, 2012; Suleman, 2014)
Classroom Layout	Placement of furniture	(Yang et al., 2013)
Sound Intensity	Sound's per-unit-area perpendicular power	(Abdou & Guy, 1996; Maekawa)

Reverberation Times	Time for a room's sound to decay across a specified dynamic range	(Mealings, 2022; Mikulski & Radosz, 2011)
Speech Intelligibility	The extent of speech comprehensibility	(Levi et al., 2007; Mikulski & Radosz, 2011)
Sound Insulation	Soundproofing measures	(Hopkins, 2003; Sivanantham et al., 2019)

Source: Siregar, 2025

The eight factors generated in the second step can be grouped into the architectural and acoustic aspects. In the third or final step, these eight factors are cross paired between architectural and acoustic aspects, and the experts were asked to choose one of the two factors. The Semantic Differential Method was used to assess this step with scoring: Not Important = 1, Slightly Important = 2, Important = 3, Important = 4, and Very Important = 5. Factors that have a value below four are eliminated, and the result is to get the three most essential factors in designing classroom acoustics in Indonesia.

RESULT

The first-round questionnaire listed acoustics classroom design factors that directly affect students' ability to concentrate by asking an open question to the three-group respondent. Then, the second round of questionnaires was followed to rank the acoustics factors. From Table 3, Speech Intelligibility (Mean = 4.30), Reverberation Time (Mean = 4.23), and Sound Insulation (Mean = 4.13) have the highest mean score, meaning that these factors have a more important role in acoustic classroom design. The same table also shows that classroom layout is less critical for acoustic classroom design; the value is 3.63. Therefore, various considerations must be prioritized before planning a classroom.

Table 3. Descriptive Statistics

Factor	Min	Max	Mean
Window and Door	2	5	3.80
Room Shape	2	5	3.73
Surface Material	2	5	3.90
Classroom Layout	1	5	3.63
Sounds Intensity	1	5	3.80
Reverberation Times	3	5	4.23
Speech Intelligibility	3	5	4.30
Sound Insulation	3	5	4.13

Source: Siregar, 2025

The third round of the questionnaire is given back to the question of which factors have more attention to be a priority. These factors are described in Figure 1. Figure 1 shows that Reverberation Time, Speech Intelligibility, and Sound Insulation have higher scores, and these three factors should be emphasized more in classroom design. Architectural factors

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play a relatively minor role in the acoustic design of classrooms. The effectiveness of classroom acoustics has a direct impact on student's ability to concentrate. Unfortunately, most people often ignore the acoustic factor that affects their academic grades.

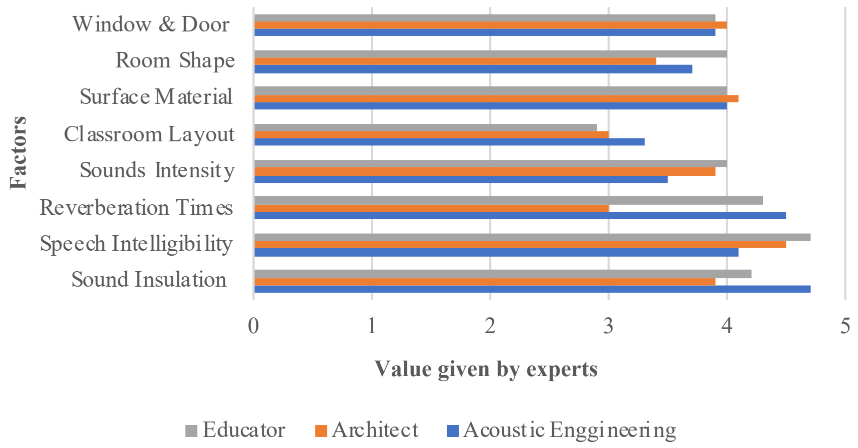

Figure 1. The second-round questionnaire comparison result
Source: Siregar, 2025

From the acoustic engineering point of view, the most important factors to consider when designing a classroom are reverberation duration and sound insulation (Figure 2a). They mostly agree that a 60 dB initial reverberation period is required for sound attenuation when the sound source is turned off. In addition, sound insulation can be done to prevent sound waves from entering a room. This goal can be achieved by building a barrier between the room and the sound trying to enter.

As seen in Figure 2b, the reverberation time (RT), from the architect's point of view, has a relatively low value. However, from the acoustic engineer's group results, it is the essential component. Both educators (Figure 2b) and instructors (Figure 2c) agree that speech intelligibility should be prioritized when designing a classroom. Speech intelligibility is the most significant factor to consider during the design process. When communicating through voice, speech intelligibility is an assessment of how easily speech can be understood in each set of conditions. The extent to which clarity is gained can be affected by how easily one can understand what is being said. Understanding much information explained by the instructor is one of the most effective ways to achieve perfect achievement at the level of education.

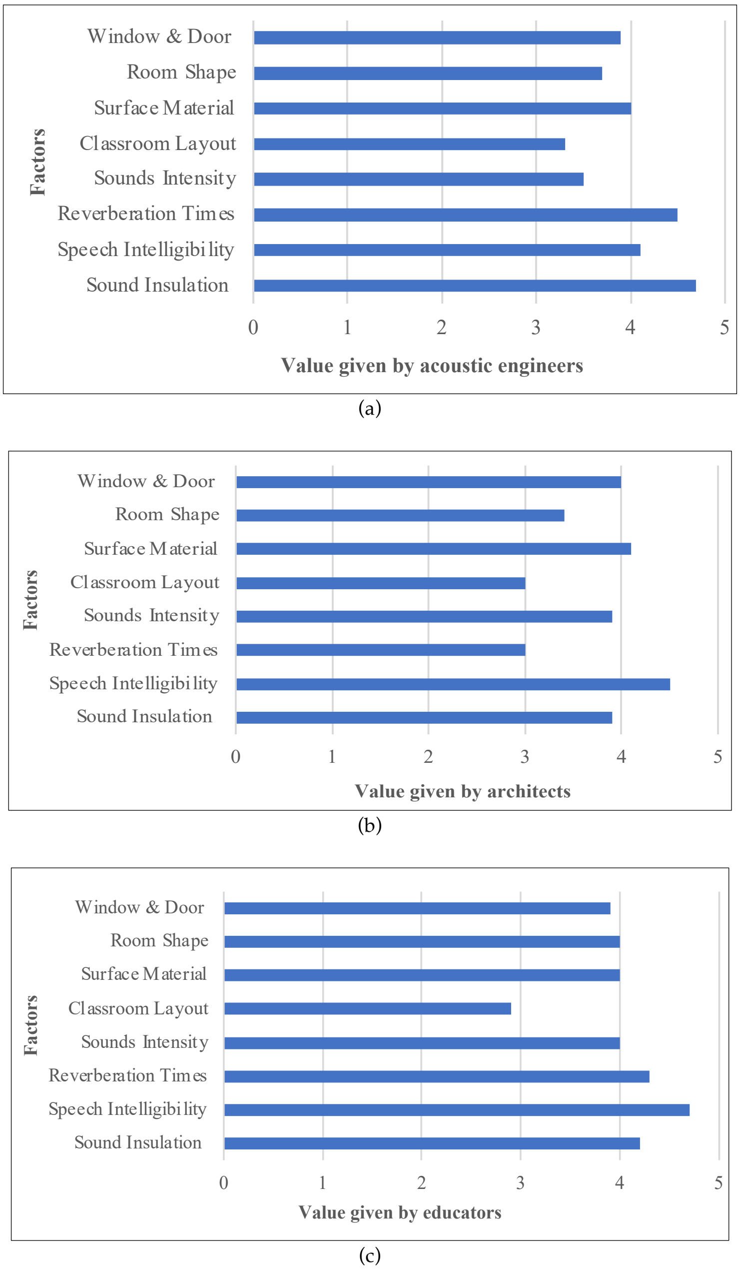

Figure 2. Second round questionnaire: (a) Value factors given by acoustic engineers group, (b) Value factors given by architect group, (c) Value factors given by educator group
Source: Siregar, 2025

Kruskal-Wallis Test was conducted to examine the differences in classroom acoustics design factors according to the occupation groups. Significant differences (Chi-square = 12.137, p = .002, df = 2) were found in one factor (Reverberation Times) among the eight classroom acoustics design factors. Reverberation Time is the most significant factor because it is considered the most influencing factor in a room's acoustic design. The ability to catch the instructor's explanation in class depends on the age and mental health of the students. When students cannot capture the instructor's description in class, it can interfere with their performance, especially regarding speech intelligibility and sentence comprehension tasks.

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Figure 3. Interior classroom with perforated ceiling panels to improved acoustics
Source: Siregar, 2025

The classroom design shown incorporates key acoustic considerations that enhance speech intelligibility and reduce noise. The perforated wooden ceiling panels serve as effective sound absorbers, allowing sound waves to pass through the perforations into underlying absorptive materials, thereby minimizing reverberation and echo. The use of carpet or other sound-dampening flooring further reduces impact noise from movement, while the strategic layout of desks ensures even sound distribution from the instructor to students. Reflective surfaces, such as whiteboards and windows, are balanced with absorptive materials to prevent excessive sound reflection, creating an acoustically balanced environment conducive to learning.

Table 4. Kruskal Wallis Test on Classroom Acoustics Design Factors

	Window & Door	Room Shape	Surface Material	Classroom Layout	Sounds Intensity	Reverberati-on Times	Speech Intelligibility	Sound Insulation
Kruskal-Wallis H	1.179	2.224	1.402	.766	1.003	12.137	3.936	3.795
df	2	2	2	2	2	2	2	2
Asymp. Sig.	.555	.329	.496	.682	.606	.002	.140	.150

DISCUSSION

When a sound source is abruptly cut off, the number of times the sound in a room dissipates over a particular dynamic range, typically 60 dB, is referred to as the Reverberation Time (RT). When performing their jobs, acoustic engineers are frequently tasked with measuring the RT in rooms that vary significantly in terms of dimensions, configurations, and the activities that take place there. As part of this extensive study on the methods used to measure RT, an effort was made to identify the optimal setup that should be applied to RT measurements to obtain the most accurate results. In addition, the measure is done to determine what factors most influence the acoustics in a room, especially in designing the acoustics of a classroom.

During a conversation, the volume drop is caused by the low reverberation time; the reverberation time standard recommended in many studies suggests RT below 0.4 seconds. According to conventional belief, younger students in elementary schools will get the most out of educational settings with RT of 0.6 seconds or less(Jo et al., 2022). An optimal RT may be required to obtain the desired level of speech intelligibility. To give just one example has been suggested that U50 > 1.0 is sufficient to achieve a satisfactory level of speech intelligibility (Bradley, 1986). RT in empty classrooms is measured and adjusted to achieve an appropriate level for each class occupied (Hodgson & Nosal, 2002). In such cases, it is crucial to provide a complete description of the room acoustics in terms of Reverberation Time in other octave frequency bands, which should have been included in the scope of this study (Bistafa & Bradley, 2000).

From a design perspective, material selection plays a vital role in achieving optimal classroom acoustics. Sound-absorbing materials such as perforated wooden panels with acoustic backing, mineral wool ceiling tiles, acoustic fabric panels, and carpet or vinyl flooring with underlay can significantly reduce RT and improve speech clarity (Kuttruff, 2016). In Indonesian classrooms, studies have shown that replacing reflective wall surfaces with perforated gypsum or installing fabric-covered acoustic panels can reduce RT by up to 40% (Prasetiyo et al., 2018). Furthermore, the use of heavy curtains for windows and acoustic baffles on ceilings has been found effective in controlling mid-to-high frequency reflections (Pasamurti & Iyati, 2018).

In Indonesia, some architecture students need to receive adequate acoustic material depth in their coursework (Hasbullah et al., 2011). As a direct result of this, the acoustic standards of many buildings in Indonesia need to catch up to what is adequate. In addition, the questionnaire results show that reverberation time is essential for acoustic engineering and educators. Still, it is not a factor the architect's group considers critical. This low attention can cause many buildings in Indonesia, especially classrooms, to have RT values that do not comply with ANSI standards. Survey responses from architects in Indonesia indicate that reverberation duration is often treated as a minor factor, leading to poor acoustics in many schools, despite its importance for supporting the learning process (Pasamurti & Iyati, 2018; Sabtalistia, 2020).

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It is necessary for architects, regardless of their work location, to understand all the factors that play an essential role in designing acoustics so that they meet the required standards. Speech intelligibility, one of the most important performance indicators, is closely related to RT, while sound insulation also influences RT. Perspectives from both architects and educators in Indonesia highlight that classroom layout is seen as a less critical factor compared to material selection and room finishes. However, integrating both architectural design and material choice can yield a significant improvement in classroom acoustic quality, ensuring an environment that supports effective teaching and learning.

This research asses the most influential factor in classroom acoustic design by collecting opinions and reports from experts willing to share their perspectives. The respondents are experts, and in addition to their roles as users of classrooms, they are frequently directly involved in the design process for classroom acoustics. They have their perspectives, yet all those perspectives are interconnected and related to one another. For example, speech intelligibility is closely connected to Reverberation Time, and Sound Insulation influences Reverberation Time. Architects and educators in Indonesia share a common point of view, including the following: classroom layout is a slightly according to architects and educators in Indonesia, the rant factor. The classrooms' layout and contents are less influential on the actors' design in Indonesia.

CONCLUSION AND SUGGESTION

An acoustically optimized classroom will facilitate learning. This study aimed to ascertain the significance of architectural and acoustic design elements for classrooms in Indonesia, as seen by architects, acoustic engineers, and instructors. The results of three rounds of questionnaires reveal that the primary considerations for acoustic engineers in classroom design are: (1) Reverberation Time (RT), (2) Speech Intelligibility, and (3) Sound Insulation. The maximum reverberation time in a classroom under 10,000 cubic feet is 0.7 seconds with a background noise level of 35 dBA. Nonetheless, architects deemed RT less significant, potentially owing to insufficient exposure to acoustic material knowledge in their curriculum. This indicates that architecture courses in Indonesia should prioritize acoustics to achieve improved design results. The attainment of optimal acoustic conditions is significantly influenced by the selection and arrangement of interior materials. Sound-absorbing materials, including perforated wood or gypsum panels with acoustic backing, mineral wool ceiling tiles, carpeted floors, fabric-covered wall panels, and heavy curtains, can markedly decrease reverberation time and enhance speech intelligibility. Similarly, solid and well-sealed wall assemblies can improve sound insulation, reducing external noise infiltration.

Speech intelligibility is closely linked to RT and is influenced by both interior materials and room geometry. In classrooms where Indonesian is the primary language, optimal RT and speech clarity targets should be studied further, as vowel and consonant characteristics can affect acoustic performance. Additionally, since many educational institutions are in dense and noisy urban areas, exterior sound isolation is essential to protect classrooms from intrusive environmental noise. Future studies should not only refine optimal RT, speech intelligibility, and insulation values for Indonesian classrooms, but also evaluate the integration of acoustic principles into architectural education.

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