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Renew the acoustics of the classroom by default

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***Abstract*---**The design of acoustics in the classroom relates to standards that provide clarity of speech for the student and acoustic comfort for the teacher. This research aims to improve the acoustics of a virtual classroom situation through three parameters: RT60 reverberation time, STI, and sound purity C50, and linking them to classroom-related acoustic quality standards. The classroom is located in a middle school characterized by its prefabricated building in Baghdad. In this study, audio simulation was used through the Odeon application. The simulation was carried out in two stages. The first stage is an audio simulation of the reality of the classroom, and the second stage is after proposing a solution The simulation results for the proposed solution showed that it conforms to the international standards represented by the French standard for educational buildings for RT60, the ISO_9921-2003 standard for the STI value, and the Din-18041-2004 standard for the C50 parameter, thus an effective sound improvement was achieved.

***Keywords*---**acoustic simulation, acoustic parameters, speech transmission indicator, architectural acoustics, architectural acoustics, reverberation time.

Introduction

It is important for the architect to have the necessary knowledge and skill to create sound environments, especially with regard to the acoustic aspect, and to have the skill to use acoustic simulation programs such as Odeon (Al-Tamimi, Abuelzain, & Qahtan, 2017)In order to achieve the integration between the design

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process and the parameters of sound quality (Alves & Laura Estévez Mauriz, 2016) It is noticeable in the experience of prefabricated construction with mass production, which is economical and saves the time required for implementation. They are often at the expense of the performance standards for space users, and the acoustic standards are one of them. (Al-Khafaj, Abdul Razzaq, & Abboud , 2011) . As the effect of the internal characteristics of the closed space and its design elements appear on the individual through dispersal and distraction, and thus affect his productivity (Al Dabbagh & Al Khazaali, 2017). Small projects whose designs are created by the architect, especially those related to sound such as classrooms and others, need even simple knowledge to achieve in their good acoustic environment, whether by relying on manual calculations or digital enabling tools. Abdelhameed & Al Kuheji study indicated that most architects lack experience in how to connect Actual practice of building by technical design (Al Kuheji & Abdelhameed, 2019). Architecture allows us to modify the sounds we create for our functions in our designs. After the audio simulation was related to the performance buildings, it withdrew to include the rest of the buildings and their various specializations. Advances in audio simulation and prediction techniques helped the architect delve into the acoustic phenomenon, as computer models enabled the production of data, animation, visualizations, and definitions of audio performance. (Peters, 2010).

One of the requirements for effective teaching in the classroom, in addition to clarity of speech, is good sound quality. The decrease in sound quality leads to repetition in speech, which creates dispersion and confusion among students and has a negative impact on the student's understanding of the content presented in it (S. Sarlatia, 2014) With the importance of taking into account the ages of the students when providing the appropriate circumstance to convey the verbal content to the students (RADOSZ, 2013) Good acoustics design and a good academic level are related to a direct relationship between them. Factors affecting students' hearing quality can be determined by background noise and reverberation time. Several studies have indicated the negative effects of background noise and its effect on the clarity of speech, its effect on the efficiency of education and the well-being of both students and teachers. (Ayman I. Madbouly, 2016). Roy mentioned in his study that there are three factors related to the geometry of the room and affecting the clarity of speech, which are the total size of the room, the shape of the room and its surface treatments. (Roy, 2016). In addition to the quality of the heating and ventilation system used in the classroom. As well as the finishing materials used in it, with the need to achieve the reverberation time recommended for the classroom. With the increase in class size, the reverberation time increases and the reverberation time decreases when using sound-absorbing material. The direction and location of the classroom in relation to noise sources also affects the quality of the acoustics in it. (Abakar & Alibaba, 2019). Therefore, the RT60 allowable reverberation time and the maximum N allowed for background noise are often sought. The impact of the quality of acoustic parameters is not only on the clarity of speech in the classroom, but also includes health and perceived quality of life for teachers, which constitutes an unfavorable environment for their performance. (Levandoski & Zannin, 2020.)

The lack of clarity of speech in the classroom negatively affects the students, the educational aspect, and the reason for the presence of reverberation time. This causes both the teacher and student to become unfocused, so the problem is how to use the change in space size through the secondary sound-absorbing ceiling in the classroom. The purpose from the search to achieve high-quality listening for both the teacher and the student through objective measurements that comply with international standards. And Studying the reality of the separation condition and analyzing the auditory environment through the reverberation time RT_{60} and the speech transmission index coefficient STI, and Clarity C_{50} identifying sound problems and proposing the appropriate solution to achieve the echo time coefficient that complies with international standards for audio categories through the simulated enabler using the Odeon application.

Materials and Methods

The research adopted the descriptive approach in clarifying the research problem within the boundaries of the semester, as well as the applied approach through the use of audio simulation represented by the Odeon application. To find out the values of the acoustic parameters represented by the Reverberation time and speech transmission indicator and the speech clarity parameter for a class located in a vocational school in Baghdad city - Iraq. Compare these standards with the standards that must be achieved in the classroom. The comparison was made before and after the solution was proposed.

Audio parameters chosen for simulation
Reverberation time RT_{60}

The RT_{60} is defined as the time required for the sound pressure level to decrease by 60 dB after the sound source stops (González, Colnaghi, & Nunes, 2018).

Speech Transfer STI

It is one of the objective measures to evaluate the sound of closed spaces due to the need to understand the information transmitted by sound in closed spaces, for example, in classrooms, halls, and others. This parameter depends on the background noise in the enclosed space and the reverberation time, which are the main factors affecting the clarity of the sound. (Montoya Párraga, 2019) It is also related to subjective evaluations and is easily computed so it is used in simulations to predict possible performance improvements (Howard & Angus, 2017). Figure 1. Shows the classification of bands for assessing clarity in rooms according to the value of STI.

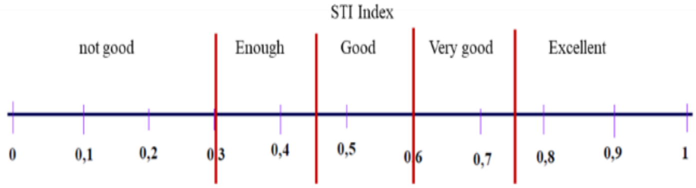

Figure 1. Showing the STI. Scale STI *(cammarata, 2017)*

Clarity C_{50}

The C_{50} parameter represents the relationship between the energy received in the 50 milliseconds of direct sound arrival and the energy latched over 50 milliseconds. It is assigned to speech spaces and is inversely proportional to frequency. (Jack Harvie-Clark, 2013)

Case study

A study related to the acoustics of a classroom in a vocational school in Baghdad. Figure 2. Illustrates the reality of the classroom and the type of finishes from the inside, where the prefabricated concrete panels form the roof of the row and the walls are ready-made cement panels as well. The lengths of the sides of the classroom are 10.87 m, 11.50 m, 7.15 m, 3.6 m, 3.72 m, and 7.90 m. And a height of 4.2 m. A three-dimensional model was created using Sketchup program according to the location detection of dimensions.

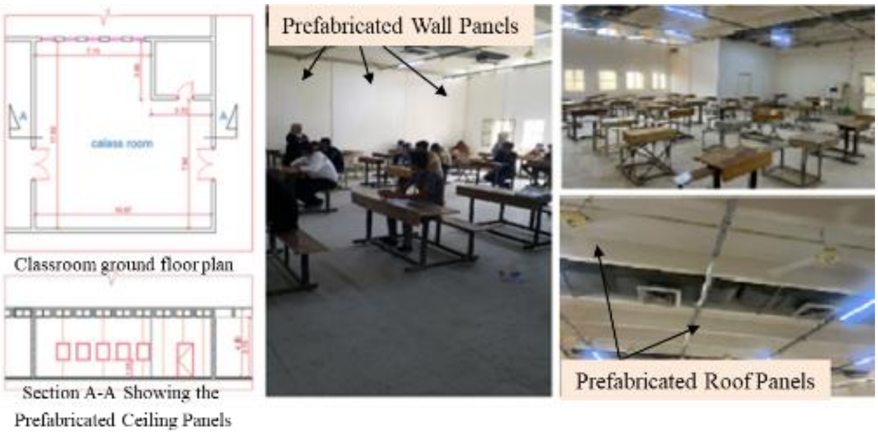

Figure 2. Showing the Classroom's Perception from the Inside. Source: the two researchers

Then the shape was exported to Odeon using the SU2odeon utility to make the onomatopoeia. And allocating the finishing materials to perform the phonetic calculations and evaluate the parameters in the different receiver positions, to evaluate the vocal performance of the speech effectiveness, to identify the existing phonemic problems and to suggest the most appropriate solution. The focus was on the RT_{60} parameter and the STI parameter, and the C_{50} parameter. The engineering approach was used for simulation through early scattering method ESM, image source method ISM, ray tracing RT_{60} and ray radiation method RRM. The first three methods are used in the calculations of early reversals. As for the fourth method, in calculating the late reflections. In the case of the point source, the calculations are made using the late reflection parts and the early reflection parts. In the linear source, the late reflection part is used. The standards ISO 3382-1 and IEC 60268-16 are approved. To calculate the RT_{60} and. STI.

Results and Discussions

Reverberation time measurements for the situation

4 receiving points and a sound source are designated as shown in the figure3. The simulation results for the RT_{60} class ranged between (0.88-4.35) seconds, across the frequency spectrum and the average value is 2.18 seconds. As in figure 4.

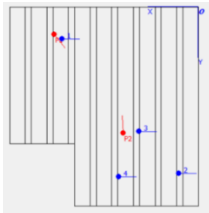

Figure. 3. Locate both the source and the receiver in Odeon

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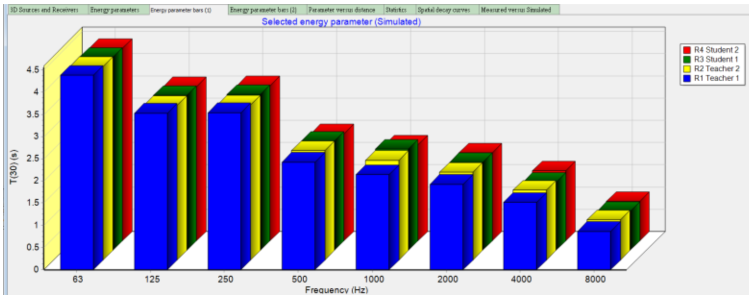

Figure. 4: RT_{60} results for the space studied in Odeon

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Within an average frequency of 3 central octaves (500, 1000 and 2000 Hz), which is higher than 1.2 seconds, it exceeds the value specified in the French standards 1.2 seconds for this type of space of educational institutions. (Development, 2003, p. 9102) Figure 5. Shows the acoustic map of the RT_{60} distribution in the classroom for both the source and the recipient.

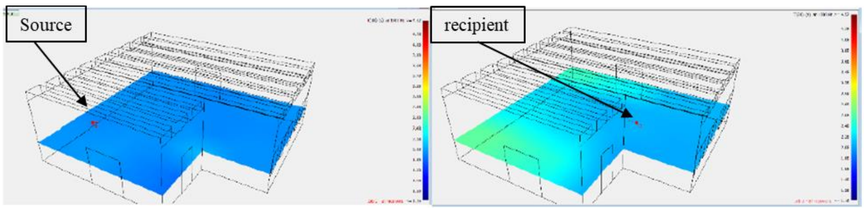

Figure. 5. Acoustic map of the RT_{60} distribution in the Odeon.

Measurements of the speech transmission index STI

It is considered a parameter related to speech intelligibility and based on the simulation for the classroom the STI value is 0.48. In accordance with the ISO_9921-2003 standard, it states the necessity of achieving the minimum for this parameter, which is 0.6 in order to obtain good speech clarity, but we do not find it achieved. Figure 6. Shows STI maps of both source and receiver.

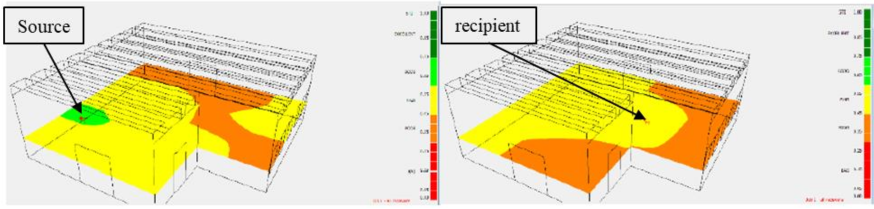

Figure. 6. STI acoustic mapping of the studied space in Odeon.

Clarity Measurements C_{50}

The C_{50} parameter is very important in relation to how well speech is understood. Figure 7. shows. Speech clarity graph. In order to have good speech intelligibility, a value of 3 must be reached for the equivalent speech frequency (250 to 8000 Hz) based on the Din-18041-2004 standard which is not achieved.

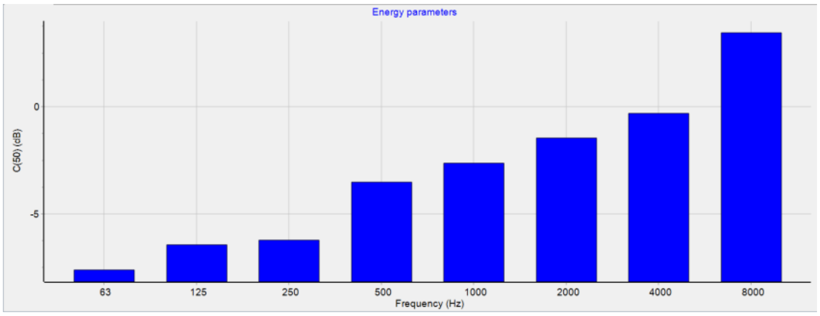

Figure. 7. C_{50} calculation of the studied area in the Odeon.

Suggested audio processing

The research suggests adding a secondary roof to the entire roof area, with an area of approximately 111 m². The research suggested a perforated metal roof that is 20% of the perforated area, and behind this mineral layer is a fibre layer with a Rockwool absorbency of 50 kg / m3 and is fixed on the metal plate with a distance of no less than 30 cm under the ready-made concrete ceiling. Among the advantages of this solution: It is light weight, its components It has recyclability, long life cycle, is characterized by durability, easy cleaning, easy maintenance, ability to absorb sound well, especially low and medium frequencies without damping out high frequencies, which is important in verbal efficiency, and it is considered a solution with a rather low cost. The characteristics of the solution can be identified. Suggested by the source. (Metal Ceilings Tiles Create a Sustainable Building Option, 2014). (Sustainable Products for Every Space, 2022),(Chusid, 2009) Figure 8. Displays the acoustic properties of the proposed solution from Odeon Library.

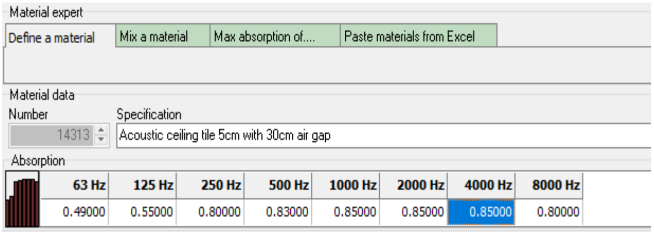

Figure 8. The acoustic properties of the proposed solution from Odeon Library

RT$_{60}$ measurements after acoustic solution implementation

The acoustic simulation showed the classroom and by adopting the same previous reception points and after implementing the acoustic solution on the entire ceiling area, the sound reflection from the walls and floor will be limited with the energy of sound reflections varying according to the location of points. Figure 9. It shows the values of RT$_{60}$ after executing the audio solution, figure 10. shows the Acoustic map of the RT$_{60}$ distribution and figure 11. Shows the average value of RT$_{60}$ after performing the acoustic treatment.

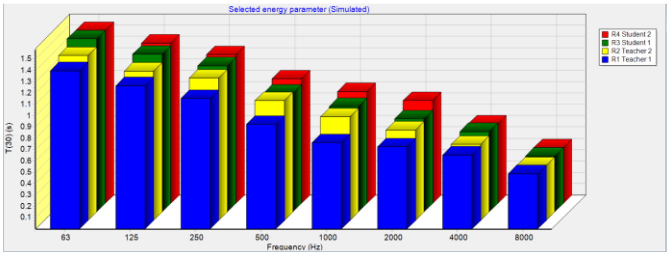

Figure 9. RT$_{60}$ value after executing the solution

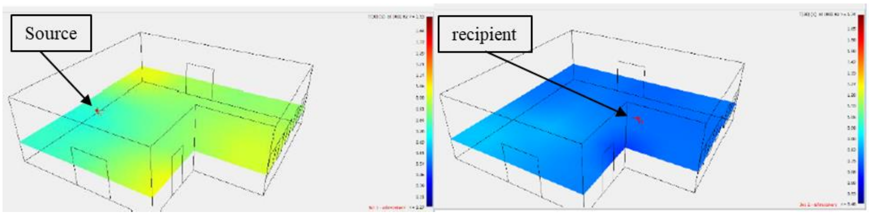

Figure 10. Acoustic map of the RT$_{60}$ distribution in the Odeon

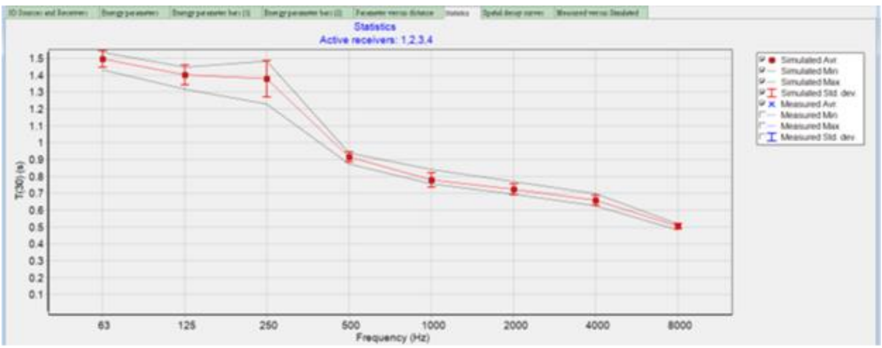

Figure. 11. Average RT$_{60}$ values after executing the solution.

It can be seen from Figure 11. The value of RT60 varied from 1.5 to 0.6 seconds across the frequency spectrum with an average value of 0.95 seconds which indicates an average frequency of a central 3-octave band (500, 1000 and 2000 Hz) that falls within the 1.2-second limit for such space.

Speech Transmission Index STI after acoustic solution implementation

The value of the STI after the implementation of the solution ranged (0.65 - 0.79) across the area, with an average value of (0.72), and figure 12. It shows the STI audio maps after the audio solution has been applied.

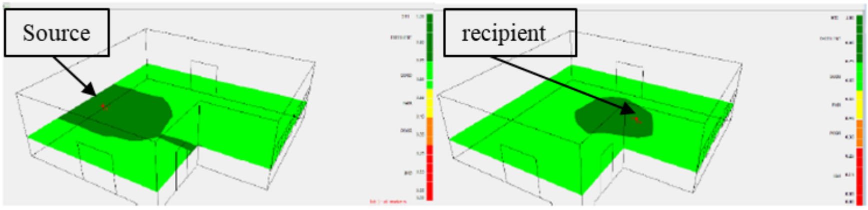

Figure. 12. STI audio mapping after solution implementation.

Clarity Measurements C_{50} after acoustic solution implementation

The C_{50} measurements after implementing the acoustic solution indicated good speech clarity because it exceeded 3 for the entire speech frequency range (250 to 8000 Hz). Figure 13. Shows the average values of speech intelligibility for the studied area after implementing the solution.

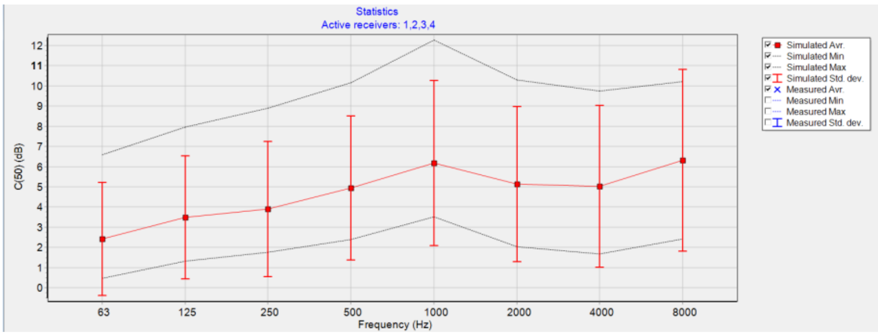

Figure. 13. Average values of C_{50} after implementing the solution.

Conclusion

The integration of acoustic design and architectural design, understanding of acoustic phenomena and acoustic properties of materials, verification and testing of objective acoustic parameters and their comparison with international standards enhance and support architectural design decisions. Effective improvement of classroom audio quality. The results of the proposed solution showed values that comply with the international standards represented by ISO, E. 9921 for the parameters. RT_{60} and STI, and Achieving C_{50} value according to the Din-18041-2004 standard, using modelling and acoustic simulation software. This audio processing for the current classroom will contribute to improving and enhancing the quality of learning. We hope that this knowledge will help in developing tools that enable the architect to add sound performance to his designs and thus achieve integration with the rest of the plans.

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References

Abakar, K. M., & Alibaba, Z. H. (2019). Acoustic Improvement of School Buildings. *United International Journal for Research & Technology, 01*(05), 22-30.

Acoustic performance as a design driver: sound simulation and parametric modeling using Smartgeometry. (2010). *International Journal of Architectural Computing*, 337-358.

Al Dabbagh, S. M., & Al Khazaali, L. K. (2017). Positive Distraction and Passive Dispersion in the Interior Space of Office Buildings. *The Iraqi Journal of Architecture*, 94-113.

Al Kuheji, M., & Abdelhameed, W. (2019). Acoustic Simulation in School Architectural Design. *IEEE.* Manama, Bahrain.

Al-Khafaj, A. M., Abdul Razzaq, A. M., & Abboud , O. A. (2011). Building performance: A study for evaluate prefabricated residational buildings performance. *The Iraqi Journal of Architecture, 22-23*, 1-23.

Al-Tamimi, N., Abuelzain, O., & Qahtan, A. (2017). Assessment of Sustainable Concepts and their Application in Architecture Educational Systems in Saudi Universities. *Journal of the Union of Arab Universities for Engineering Studies and Research, 2.*

Alves, S., & Laura Estévez Mauriz, L. E. (2016). Applied urban sound planning. In *URBAN SOUND PLANNING - the SONORUS project* (pp. 69-114). Sweden: Chalmers University of Technology , Division of Applied Acoustics .

Ayman I. Madbouly, A. Y. (2016). Assessment model of classroom acoustics criteria for enhancing speech,intelligibility and learning quality. *Applied Acoustics, 114*, 147–158.

Cammarata, G. (2017). *Acustica Applicata.*

Chusid, M. (2009). Perforated Metal and Wood Ceilings: Sustainability, Acoustics, and Aesthetics.

French Ministry of Ecology and Sustainable Development, Arrêté du 25 avril 2003 relatif la limitation du bruit dans les établissements d'enseignement (decree of 25 april 2003 relative to the noise limitation in educational

González, M. S., Colnaghi, J., & Nunes, O. M. (2018). Acoustic analysis of the Padre Werner Unisinos auditorium. *Revista Ingeniería de Construcción, 33*.

Howard, D. M., & Angus, J. S. (2017). *Acoustics and Psychoacoustics.* New York: Routledge.

Jack Harvie-Clark, N. D. (2013). The practical application of G and C50 in classrooms. *In Inter-noise and noise-con congress and conference proceedings, 247*, 1510-1520.

Levandoski, G., & Zannin, P. H. (2020.). Quality of Life and Acoustic Comfort in Educational. *Journal of Voice*, 1-8.

Metal Ceilings Tiles Create a Sustainable Building Option. (2014, September 4). (metal ceiling express) Retrieved from https://www.metalceilingexpress.com/blog/metal-ceilings-tiles-create-a-sustainable-building-option/

Montoya Párraga, L. C. (2019). *La forma, la acústica y el revestimiento de materiales en el auditorio León de Greiff.*

Radosz, J. (2013). Global Index of the Acoustic Quality of Classrooms. *PAN, 38*, 159–168.

Roy, K. P. (2016). Global case studies of acoustics in classrooms. *the 22nd International Congress on Acoustics (ICA 2016).* Buenos Aires, Argentina.

S. Sarlatia, Z. H. (2014). The Importance of Acoustic Quality in Classroom. *Jurnal Teknologi(Sciences & Engineering)*, 71-76. settings). Paris, France, 2003.

Sustainable Products for Every Space. (2022). (Armstrong ceiling&wall solutions) Retrieved from https://www.armstrongceilings.com/commercial/en/performance/sustainable-building-design/sustainable-ceilings.html#:~:text=METALWORKS%20Ceilings%20%26%20Walls,%2Dcycles%2C%20reducing%20construction%20waste