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# Refurbishing Classrooms for Hybrid Learning: Balancing between Infrastructure and Technology Improvements

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# Refurbishing Classrooms for Hybrid Learning: Balancing between Infrastructure and Technology Improvements

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**Abstract:** The COVID-19 pandemic has posed significant challenges to all facets of education. As students are slowly repopulating university campuses after lockdowns and online learning, universities are looking into ways to ensure social distancing can be maintained in learning spaces and capitalize on the benefits of online-learning modalities without compromising educational quality. One option that has gained attention is hybrid or dual-delivery learning. In this model, some students are present in classrooms, while others join the class through online platforms. However, most university classrooms are not designed to deliver the voice of instructors and classroom students to online platforms. This change in modality requires universities to invest in infrastructure and technology. This research studies the optimum setup for dual-delivery classrooms, investigating a range of infrastructural and technology improvements that can be made to traditional classrooms to help optimize the perceived sound quality for remote learners. The investigation entails a qualitative study to assess the improvement in perceived sound quality (clarity, ability to recognize words, and perceived echo) for remote students vis-a-vis the improvement in the room (such as sound-absorbing padding or carpets) and its technology (such as ceiling and lapel microphones). Specifically, it investigates the degrees of room and the technology improvements needed to ensure that the voice of instructors and the classroom students' interactions, such as questions and discussions, are heard and comprehended by remote students. We collected responses for nine experiment conditions through 39 tests addressing both instruction and students' interactions. We formulate a matrix of recommendations for higher education institutions to follow. The suggestions proposed also have other environmental benefits beyond sound quality.

**Keywords:** hybrid teaching; post-COVID; education; sound; classroom

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## 1. Introduction

During the COVID-19 pandemic, universities were forced to move all teaching activities online to limit the spread of the virus and deal with imposed lockdowns. Information and communication technology has played a vital role in the advancement of education and the revolution in learning methods. Within the COVID-19 pandemic, online teaching has developed rapidly, turning the traditional classroom into a virtual place that can meet the diverse needs of students. It has also afforded greater flexibility to students, especially those living in remote locations. New technologies have allowed stakeholders in the educational setting to share knowledge and understanding and develop shared values [1].

However, complete remote or virtual learning, which entails no physical interactions, has several drawbacks. Students, especially fewer independent learners and those who have less ability to self-monitor, tend to be lost or overwhelmed during the course; they struggle to remain motivated [2,3] and miss out on the guidance and encouragement they would traditionally receive from their instructors their peers. As universities reopen their campuses, many institutions are exploring the potential to advance their online teaching offerings to continue to afford more flexibility for students, limit on-campus student density, and capitalize on the lessons and investments made in online information and communication technology tools during the pandemic. As such, various educational institutions worldwide plan to continue using remote learning technologies due to their widespread acceptance and rapid development in the post-pandemic era [4].

In this context, a new learning paradigm defined as hybrid or blended learning is currently gaining attention and is emerging as a rational option. Hybrid learning entails students alternating between physical and virtual attendance of courses. The model addresses the loss of face-to-face contact between students and instructors in remote education. By dividing the class into remote and classroom students, hybrid learning combines the best features of traditional face-to-face learning with technology-based online learning [1,3–12]. Compared to e-learning, Heilporn et al. [6] and Dodero et al. [7] believe that hybrid learning fosters more student engagement. Through hybrid learning, universities can control student density in classrooms and on campus. To add to this, this hybrid model can be perceived as more environmentally friendly since it reduces the commuting needs of students and reduces disposable COVID related waste, such as facemasks [13]. However, in this hybrid teaching model, information and communication technologies remain the primary link between the participants in the educational activity, both in class and outside [5].

Since the instruction happens in a physical classroom, the challenge becomes how to transmit the classroom experience effectively to remote students. Dziuban [5] and Garrison and Kanuka [8] suggest rethinking the design of classrooms to allow them to provide an effective learning experience for students who are connecting remotely. Thus, refurbishing available traditional classrooms for dual delivery is a challenge universities are currently facing since, in many cases, existing infrastructures were not designed with this hybrid learning model in mind. A specific hurdle is ensuring that the sound of instructors and classroom students is transferred to remote students at an adequate quality.

Hybrid and blended education has been explored theoretically as part of the broader inquiry in learning theories. Picciano [14] traced the history of theories and models focused on online learning environments. They propose that hybrid learning can be understood through a multimodal model that combines collaboration, discussion, independent, social, content, reflection, and assessment components, in what they called the "Blending with Pedagogical Purpose model". Most notably, they highlight that technology, its effectiveness and fit to the pedagogical purpose becomes vital in the learning process within these hybrid models of education.

Fitting general higher-education classrooms for hybrid and remote learning is relatively new. However, the issue has been explored previously in specialized classrooms, most notably in music teaching. In the context of the Middle East, Nsairat et al. [15] investigated how students perceived music e-learning during the COVID-19 pandemic. To offer practical solutions for music education, they investigated music distance learning knowledge, attitudes, practices, and the problems experienced. In their cross-sectional study in Jordan, most respondents agreed that distance learning is applicable in the music department.

Otčenášek et al. [16] examined the integration of audiovisual communication tools and technology into music education. They highlight that the circumstances of music teaching can vary and may impact how the sound is received, affecting the effectiveness of the education in return. Their study investigated how 18 students rated various technology additions for singing courses in three classrooms. In the remote forms, the authors indicate variations in the numerous characteristics related to perceived sound; these included its temporal qualities, as well as sound and room qualities. In some cases, remote students highlight that sound quality and echo often impair their ability to learn. Their findings imply that the change in how remote learners perceive sound can hinder, in some contexts, the learning experience and have significant effects on their education. To the best of the author's knowledge, no studies investigated perceived sound quality for remote learners in general classrooms. However, discussions and exchanges between students and instructors remain a vital element in university-level teaching in most learning environments. Thus, ensuring that remote learners can adequately hear and comprehend conversations happening in the physical classroom can be seen as a critical success factor for the hybrid learning model.

This study presents an initial investigation into the readiness of general university classrooms for hybridity. Specifically, we investigate the physical and technological changes required in the classroom to ensure that instructors' voices and classroom students' interactions, such as questions and discussions, are heard and understood by remote students. We specifically investigate the improvement in perceived sound quality (clarity, ability to recognize words, perceived echo, and overall sound quality) for remote students with improvements in the room (such as sound-absorbing padding or carpets) or its technology (such as ceiling and lapel microphones).

## 2. Materials and Methods

Since the issue being investigated relates to the perceived quality of sound for remote students, we designed a qualitative study to assess the perceived sound quality for remote students vis-a-vis the improvement in the room or its technology. Similar to previous work done in the music teaching field [15,16], we focus on the perceived sound quality for remote learners—which combines the effects of the classrooms' acoustic characteristics, its equipment, the signal processing capabilities, the quality network connection on campus and in remote-learning locations, the quality of the personal devices used by remote students, as well as physiological factors and individual preferences.

Thus, we use Likert-type scoring methods from human subjects instead of measuring room acoustics. As mentioned by Otčenášek et al. [16], although multichannel or uncompressed audio and video transmissions over the network and high accuracy of perceived environment reproduction can be achieved [17], these conditions are not commonly met in practice due to a variety of constraints, including those related to environment settings or transmission chain. Accordingly, conditions such as room coupling or reproduction procedures, which may alter the perceived attributes of the sound source or environment, might still influence the transmitted sound in hybrid teaching and learning.

We conducted the tests in a standard classroom at the American University in Cairo, with a podium at the front and 20 to 25 individual desks distributed based on social distancing guidelines (at least 1.2 m apart). Figure 1 shows a standard classroom at the American University in Cairo.

**Figure 1.** Standard Classroom at the American University in Cairo. Courtesy of AUC.

We tested two situations: (1) instruction: where a teacher is speaking near the podium or at the front of the class, and (2) students' interactions: where students in the classroom are asking questions or engaging in discussions.

To improve the sound quality and limit echo, we investigate the addition of padding and carpets as possible room improvements. The sound-absorbing padding considered in this study are wood panels that are padded with 2 cm of foam and covered with sound-absorbing fabric. The carpets considered for the classroom are anti-bacterial square nylon-based, with rubber backing. We investigate the distribution of microphones over students (two or four microphones). The ceiling microphones used in the study were overhead microphones with a super-cardioid cartridge polar pattern and a receiving angle of 115 degrees. Finally, we also investigate using a lapel microphone for instruction as a technology improvement. The lapel microphone tested is a standard clip-on type with a wireless transmitter. Figure 2 shows a typical classroom refurbished with full padding and carpet and equipped with overhead microphones.

**Figure 2.** Standard Classroom at the American University in Cairo fitted with carpets and full padding for dual-delivery. Courtesy of AUC.

*Test Procedure and Limitations*

We selected two individuals with different voice pitches to emulate the teaching in the tests; the first identified as a female with a high voice pitch, and the second as a male with a lower voice pitch. We recruit 15 participants who connect to the classroom using their laptops and headphones, simulating the remote students' situation. The sample size was determined based on two factors: (1) the typical student count for remote learners in undergraduate hybrid academic courses at the American University in Cairo, and (2) the remote learning location capacity on campus with social distancing requirements. The sample size also conforms to that used by Otčenášek et al.'s [16] recent investigation, similar in nature to this study. The sample had a balance in gender and distribution in age, and none of the sample members disclosed having any learning or hearing disability.

To simulate the instruction (Table 1 and Figure 3), we carry out four tests for each condition: (1) male individual at the podium, (2) female individual at the podium, (3) male individual away from the podium, and (4) female individual away from the podium. For the four instruction conditions examined, we carried out 16 tests.

**Table 1.** Instruction conditions tested.

| | Room Condition | Technology Condition |
|---|---|---|
| Condition I1 | No padding, no carpet | Two ceiling microphones at instruction zone |
| Condition I2X | Full padding and carpet | Two ceiling microphones at instruction zone |
| Condition I3 | No padding, no carpet | Lapel Microphone |
| Condition I4X | Full padding * and carpet | Lapel Microphone |

* Full padding is defined as padding from the ground to about 3 m in height, excluding whiteboards.

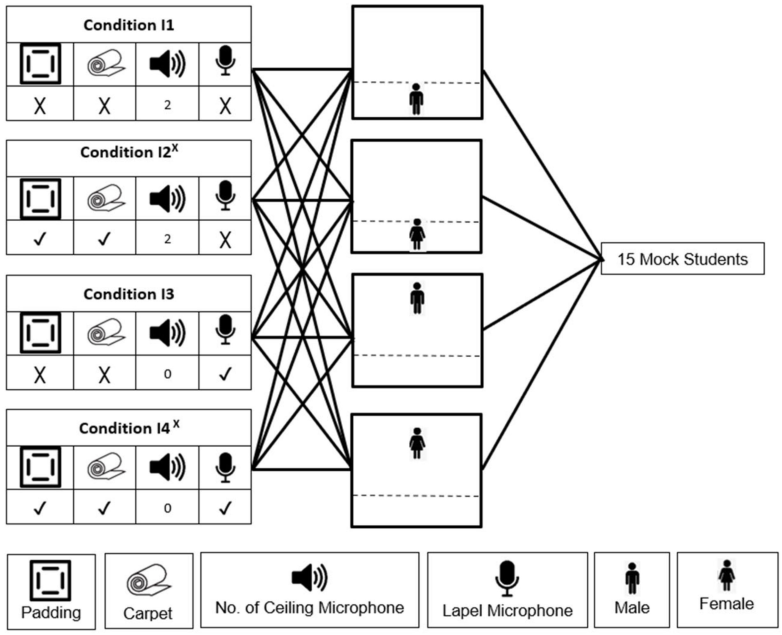


**Figure 3.** Instructions Conditions and Tests Procedural Flow Chart.

To simulate students' interactions (Table 2 and Figure 4), we carry out five tests for each condition: (1) male individual at the back right desk of the classroom, (2) female individual at the back left corner of the classroom, (3) male individual at the front right desk of the classroom, (4) female individual at the front left desk of the classroom, and (5) a discussion between female and male individuals at the two center desks of the classroom. For the five students' interaction conditions examined, we carried out 25 tests. Each test entailed reading a random list of ten sentences from the Harvard sentences designed for subjective speech quality measurement [18].

**Table 2.** Students' Interactions conditions.

| | Room Condition | Technology Condition |
|---|---|---|
| Condition S1 | No padding, no carpet | Four ceiling microphones in the student zone |
| Condition S2 | * Top padding, no carpet | Four ceiling microphones in the student zone |
| Condition S3 | Full padding, no carpet | Four ceiling microphones in the student zone |
| Condition S4 | Full padding and carpet | Four ceiling microphones in the student zone |
| Condition S5 X | Full padding and carpet | Two ceiling microphones in the student zone |

* Top padding is defined as padding from 2.2 m (i.e., from the top of whiteboards) to about 3 m in height.

The 15 remote participants, which were connected to the classroom system via Zoom, completed a survey for each test where they rated on a scale of 1 to 7 the following parameters: (1) clarity of sound (7: very clear), (2) their ability to recognize the words spoken (7: able to recognize all words), amount of echo or resonance (7: low level of resonance), and whether it hinders recognition of the sentences spoken (Yes/No), and the overall quality of sound (7: very high quality). The selection of the scale size was informed by the work of Taherdoost [19,20], suggesting the 7-point scale as the most accurate and most accessible in studies that permit users to express a neutral position to a question. A survey sample is included in Appendix A, and the description of the parameters is presented in Appendix B.

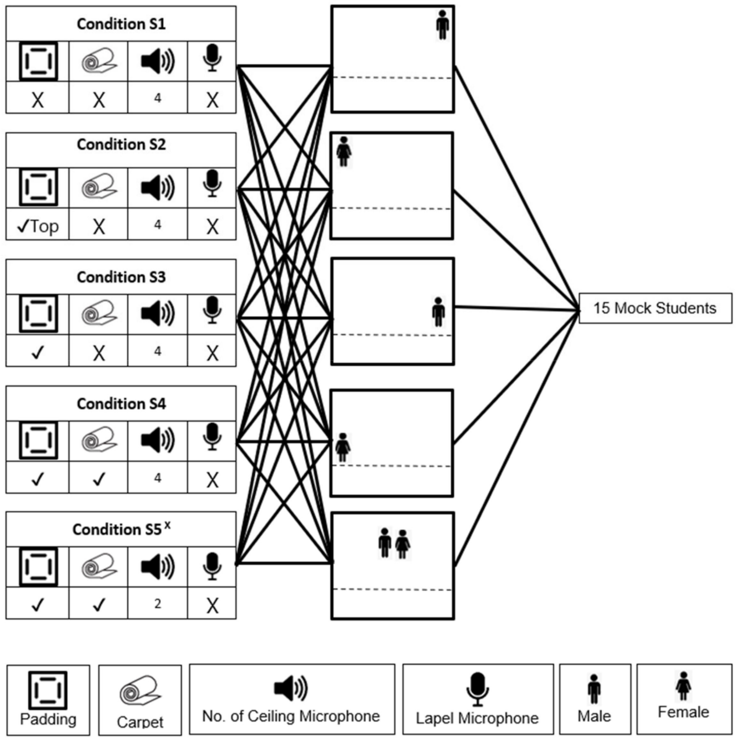


**Figure 4.** Students' Interaction Conditions and Tests Procedural Flow Chart.

While the methodology is robust, several limitations emerged. Firstly, the quality of the internet for remote participants could vary, which is an external parameter. Secondly, the remote participants' equipment, namely the laptops and headphones, was another external factor that could have affected their rating. A third external factor is the physiological variations in hearing ability within remote learner's sample. Since these three limitations are part of dual-delivery situations in real life, the researchers did not control for their effects. In addition, unintended noise leaks in the classroom (due to ventilation, exterior noises, for example), or noise at the remote students' locations are parameters that might have affected their rating and were beyond the researchers' control. Finally, two different classrooms were used during the study due to space and scheduling limitations on campus. Specifically, conditions marked with an "X" in Tables 1 and 2 were conducted in a slightly smaller classroom that featured 20 individual desks (about 65 $m^2$), whereas the rest of the conditions were tested in a classroom with 25 individual desks (about 75 $m^2$). Finally, all the equipment and room elements tested were limited by availability in the local market.

## 3. Results

### *3.1. Initial Statistical Analysis*

We collected 501 valid responses for the 39 tests from the 15 participants representing the capacity of remote learning spaces. The Shapiro–Wilk test for quality, clarity, recognition, and echo parameters returned $p$ values < 0.05, indicating that the data does not follow a normal distribution. Consequently, we used a non-parametric test (Mann–Whitney U Test) for two scenario comparisons (1-tail) along with a non-parametric correlation test (Spearman's). We use $p < 0.01$ as the threshold level of significance.

All four survey parameters are found to be correlated (Table 3). Overall quality, clarity, and recognition are positively correlated at more than 0.85 (significant positive correlation). The quality parameter has the highest correlation coefficient (close to 0.9) and is selected to represent the other two variables in further statistical tests. There is a weak negative correlation between echo and all other parameters. It is tested independently. The echo's effect on hindering understanding is also tested independently.

**Table 3.** Spearman's correlation between 4 survey parameters.

| | | Overall Quality | Clarity | Recognition |
|---|---|---|---|---|
| Overall Quality | Spearman's rho | — | | |
| | *p*-value | — | | |
| Clarity | Spearman's rho | 0.91104 *** | — | |
| | *p*-value | $1.72755 \times 10^{-132}$ | — | |
| Ability to Recognize words | Spearman's rho | 0.92327 *** | 0.87800 *** | — |
| | *p*-value | $6.62091 \times 10^{-143}$ | $1.66334 \times 10^{-110}$ | — |
| Echo | Spearman's rho | −0.39937 *** | −0.44636 *** | −0.31544 *** |
| | *p*-value | $1.73048 \times 10^{-14}$ | $4.22611 \times 10^{-18}$ | $2.58096 \times 10^{-9}$ |

*** $p < 0.001$.

We use a Mann–Whitney U Test for the two individuals who conducted the testing to examine if the voice pitch affected the parameters tested (excluding the combined tests simulating students' discussions). We found no significant difference at $p < 0.01$ across the two samples and concluded that the voice pitch had no significant effect on the sound's quality, clarity, or echo. It also did not affect the remote participants' ability to recognize the words spoken.

### *3.2. Instruction Tests Results*

Table 4 shows the average results of test parameters for instruction conditions, and Appendix C (Table A2) shows the comparison matrix between the four conditions tested. As expected, total improvements in the room (i.e., adding full padding and carpet) significantly improve the overall sound quality and reduce the echo. When comparing the fully improved room and the original non-improved classroom, we can see that the echo significantly hinders the ability of words and sentence recognition.

**Table 4.** The average results of test parameters for instruction conditions.

| | Condition I1 ($N$ = 60) | Condition I2 ($N$ = 42) | Condition I3 ($N$ = 61) | Condition I4 ($N$ = 48) |
|---|---|---|---|---|
| Overall quality | 31% | 54% | 67% | 70% |
| Clarity | 35% | 58% | 69% | 73% |
| Recognition | 34% | 61% | 71% | 74% |
| Echo | 49% | 25% | 29% | 19% |
| Echo hinders | 52% | 30% | 26% | 18% |

By comparing conditions I1 and I2 with I3 and I4, we found that using clip-on lapel microphones for instructors significantly improves the overall quality and reduces the echo and its effects. We find that room improvements do not significantly enhance sound quality and echo reduction when using lapel microphones for instruction. In other words, remote students will not find a significant difference in sound quality or echo between a teacher using a lapel microphone in an unimproved class and another in a fully improved classroom (whether using a lapel microphone or not).

### *3.3. Students' Interaction Tests Results*

Table 5 shows the average results of test parameters for instruction conditions, and Appendix C (Table A3) shows the comparison matrix between the four conditions tested. We compared how the room improvements and microphone setups affect the sound quality and its echo. When looking at the level of room improvement, we find that adding only the top part of the padding improves the conditions of the original classroom significantly. By comparing conditions S2 and S3, we find that adding the full padding in the room makes only a marginal and insignificant difference in the sound quality and echo. By comparing conditions S3 and S4, it is clear that adding the carpets does not improve the sound and resonance significantly. Participants assessed the overall sound quality at a higher level without the carpet.

**Table 5.** The average results of test parameters for student interactions conditions.

| | Condition S1 (*N* = 75) | Condition S2 (*N* = 45) | Condition S3 (*N* = 55) | Condition S4 (*N* = 60) | Condition S5 (*N* = 56) |
|---|---|---|---|---|---|
| Overall quality | 34% | 60% | 65% | 63% | 58% |
| Clarity | 34% | 64% | 73% | 65% | 61% |
| Recognition | 37% | 66% | 70% | 62% | 64% |
| Echo | 46% | 41% | 38% | 37% | 26% |
| Echo hinders | 57% | 39% | 39% | 37% | 21% |

By comparing the two- and four-microphone setups in the fully improved rooms (conditions S4 and S5), we find that the increased density does not significantly improve any of the parameters. The increased density of the microphones could be causing a higher perceived echo in the sound. Given that the microphones were almost 2 m above the sound source, which in this case is the student, there were more overlaps between the microphones' 115-degree cone of transmission, as seen in Figure 5.

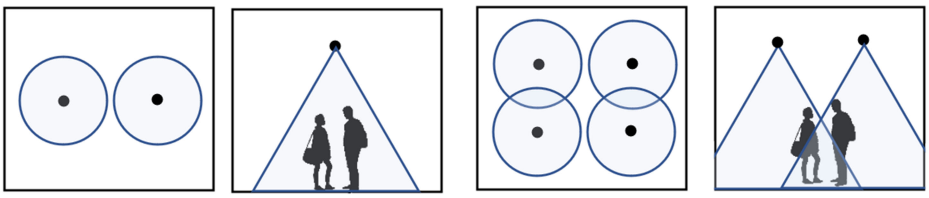

**Figure 5.** Illustration of the overlaps between multiple microphones' cone of transmission.

## 4. Discussion

This study further enforces the view of Heilporn el al. [6] and Dodero et al. [7] that rethinking traditional classrooms is needed to make them fit for hybrid learning. Additionally, the results support the findings of Otčenášek et al. [16] that the room and teaching conditions can significantly affect the perceived sound quality for remote learners. In the context of the classes tested, the quality of the perceived sound was significantly affected by both infrastructure and technology changes. In some cases, the effect of both improvements in the two domains was not synergistic.

Yet key recommendations can be extracted from the study and are summarized below.

Generally, for instruction in a hybrid learning model, a lapel microphone can provide sufficient quality for the instructor's voice with no room improvements. Also, our testing clarifies that, in general, variations in voice pitches would not significantly affect the quality of the sound for remote students.

In dual-delivery situations that resemble traditional lecturing and entail no significant input from attending students, no improvements in the classroom are required if the instructor is using a lapel or clip-on microphone. In more dynamic teaching situations, where input and engagement from students are expected, we find that using a lapel microphone might result in a noticeable gap in sound quality between instructors and students when the classroom has no improvements (i.e., padding and carpets).

When it comes to delivering students' classroom interactions to remote students, we find that a minimum of top padding should be added in classrooms. We recommend a maximum improvement of full padding with no carpet for improved sound quality. Adding the carpet did not significantly improve echo while worsening other tested parameters. Additionally, carpets complicate the cleaning and maintenance of the classroom spaces and have a relatively shorter service life, making them undesirable.

We also found that increasing the microphone density over students does not substitute for improving the room's acoustics through the padding. A higher density microphone configuration might result in perceived resonance for remote students. Furthermore, adding weather or dust stripping to doors might be appropriate for reducing background noise in all dual-delivery classrooms. It will also help minimize energy losses that result from air infiltration/exfiltration. Finally, we recommend adjusting the HVAC supply and return static pressure both in the instructor and student zones of the classrooms to reduce noise.

## 5. Conclusions

The COVID-19 pandemic has made the benefits and challenges of online and remote learning visible. Investments made in digital learning technologies and their recent rapid development have made higher-education institutions and students more accepting of their continued adoption. With many campuses reopening to students, hybrid learning appears here to stay. In this context, institutions have to continue to investigate ways to improve their infrastructure and learning spaces to adapt to these emerging needs. A critical success factor for hybrid learning is transmitting the classroom experience to remote students, including the human interactions and discussions that take place in the physical realm.

This study focused on the sound quality to investigate the levels of improvements in classrooms, both physical and technological, required to transmit different classroom interactions to remote students. The investigation yielded important conclusions using an easily reproducible methodology informed by previous studies. We recommend that institutions can utilize the current classrooms with no room improvements for dual-delivery lecture-based courses, while providing instructors with lapel microphones. In seminar-like teaching conditions, where significant input from classroom students is expected, we recommend that institutions consider a maximum classroom improvement of full padding with no carpet, and the least amount of ceiling microphones, based on the manufacturer's recommendations.

It is important to mention that this was an exploratory study that aimed to examine remote learners' perceived sound quality in hybrid classrooms. The parameters tested were limited based on the availability of materials and equipment in the local market, and responses were collected from a focus group composed of 15 individuals. As previously mentioned, the methodology deployed had several limitations. Despite the results, the methodology proved to be effective in extracting key recommendations for institutions. It also remains easily reproducible on other campuses since it requires no specialized equipment.

As this hybrid learning model becomes more widely used, further testing and experiments could be conducted to collect data in a larger number of classrooms (in the range of 100 teaching spaces) and solicit responses from actual remote students. Additionally, whereas the current study focused on learning spaces at the American University in Cairo, future testing could be conducted on more campuses to extract global best practices for dual-delivery classrooms. Other researchers may opt to study the parameters that constitute the perceived sound quality in more depth, including the room acoustics (e.g., reverberation, attack and decay, and resonance), and the digital audio signal parameters (e.g., sampling and filtering). Additionally, future researchers might consider expanding on the qualitative data analysis related to perceived sound quality by analyzing responses of remote learners to questions in an interview or text-based survey.

Finally, to consider the built spaces as biomedical systems to prevent the spread of COVID-19 and other diseases [21], investigating effective means to reduce human density becomes critical. One of such venues is hybrid learning, which combines the benefits of both physical and remote education models. This study offers simple recommendations for facilitating the transition to this hybrid model using the existing teaching and learning spaces and minimal interventions. Whereas the focus of the study was on higher education, the findings could be extended to any educational level.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A. Survey Sample

Introduction:
Thank you for taking the time to be with us today.
Instructions (Please):

1. Make sure your computer has a stable internet connection
2. Use your headphones/earphones
3. Make sure the volume is set to an appropriate level
4. Answer the questions by ranking based on what you think best represents the conditions
5. We will inform you of the test code before starting each test—make sure you select it from the drop-down list. After the test, we will confirm the test code again; please make sure it is correct.
6. We say "start of test" at the beginning and "end of test". Please only rank based on what you have heard during the test.

Questions:

- Test Code: each test is coded and is selected from a dropdown list
- Rate the clarity of the sound: 1 (very unclear)—7 (very clear)
- Rate your ability to recognize all the words/sentences spoken: 1 (Cannot recognize most of the words/sentences)—7 Can recognize all words/sentences
- Rate the amount of echo or resonance in the sound: 1 (A lot of echo/resonance)—7 (No echo/resonance)
- If there was an echo or resonance. Did it hinder your ability to understand the words/sentences spoken? (YES/NO)
- Rate the overall quality of the sound: 1 (very low quality)—7 (very high quality).

## Appendix B. Survey Parameters

**Table A1.** Description of Survey Parameters.

| Quality | Overall perceived sound quality (100% very high quality) | Echo | The amount of echo in the sound (0% no echo at all) |
|---|---|---|---|
| Clarity | The clarity of the words/sentences spoken (100% very clear) | Echo hinders | The existing echo hinders the ability to recognize the words/sentences spoken (Yes/No) |
| Recognition | The ability of participants to recognize the words/sentences spoken (100% can recognize all words/sentences) | | |
| Quality | Overall perceived sound quality (100% very high quality) | | |
| Clarity | The clarity of the words/sentences spoken (100% very clear) | | |
| Recognition | The ability of participants to recognize the words/sentences spoken (100% can recognize all words/sentences) | | |

## Appendix C. Statistical Comparisons

**Table A2.** Comparison Matrix between the Four Instruction Conditions Tested.

| | Condition I1 | Condition I2 | Condition I3 |
|---|---|---|---|
| Condition I2 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | | |
| Condition I3 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality $p > 0.01$<br>- echo, $p > 0.01$<br>- echo hinders $p > 0.01$ | |
| Condition I4 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality $p > 0.01$<br>- echo, $p > 0.01$<br>- echo hinders $p > 0.01$ |

Shaded cells indicate no significant difference. In bold are significant differences in only one of the three reported parameters.

**Table A3.** Comparison Matrix between the Five Student Conditions Tested.

| | Condition S1 | Condition S2 | Condition S3 | Condition S4 |
|---|---|---|---|---|
| Condition S2 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | | | |
| Condition S3 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality, $p > 0.01$<br>- echo, $p > 0.01$<br>- echo hinders $p > 0.01$ | | |
| Condition S4 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality, $p > 0.01$<br>- echo, $p > 0.01$<br>- echo hinders $p > 0.01$ | - Overall quality $p > 0.01$<br>- echo, $p > 0.01$<br>- echo hinders $p > 0.01$ | |
| Condition S5 | - Overall quality $p < 0.001$<br>- echo, $p < 0.001$<br>- echo hinders $p < 0.001$ | - Overall quality, $p > 0.01$<br>- **echo, $p < 0.001$**<br>- echo hinders $p > 0.01$ | - Overall quality $p > 0.01$<br>- **echo, $p < 0.001$**<br>- echo hinders $p > 0.01$ | - Overall quality $p > 0.01$<br>- **echo, $p < 0.001$**<br>- echo hinders $p > 0.01$ |

Shaded cells indicate no significant difference. In bold are significant differences in only one of the three reported parameters.

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