EXAMINING DIVERSE LEARNING SPACES
AND THEIR EFFECT ON STUDENT LEARNING

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ABSTRACT

Education has been at the forefront of all cultures since the beginning of time. Its significance, often described and held to different standards throughout the world, has often relied on its instructors, setting, and facilities. As technology develops, its role in today's schools and educational facilities grows. Many of those schools do not have the facilities to keep up with the ever-changing technologies that the instructors must use to stay relevant. This research provides architectural solutions to the shifting needs of today's learning from traditional to 21st Century environments. Educational spaces that inhibit features conducive to student learning that are also engaging for those students can bridge even the largest of cultural gaps. Research investigates and analyzes which learning methods are successful and precedents that demonstrate them. It also examines architectural layouts that best support this variety of instruction methods.

INTRODUCTION

Education is a fundamental element of human life. For hundreds of years, education has been determined by few instruction methods, yet technologies are ever changing. We have come to understand different students require different instruction, and our facilities should reflect those different methods to better serve our instructors and students. This research will determine what architectural spaces aid instruction methods used in today's schools by using knowledge framed by understanding of sociocultural engagements and also diverse realities situated in context with multiple constructed realities. An understanding of how today's learning environments and tomorrow's technologies can combine to educate and inspire our students is vital to the success of the research project. If a set of architectural standards can be set for architects to use when designing educational facilities and learning environments, teachers and instructors should have the facilities to utilize varying instruction methods in order to reach a larger portion of their students. Flexible spaces are the key. Classrooms that allow for the rearranging of the space from activity to activity signify a possibility to switch from small group learning and individual work, to large, full class instruction. OWP/P Architects, VS Furniture, and Bruce Mau Design state in *The Third Teacher* (2010) that a diversity of learning environments allow students to learn based on their individual strengths (p. 72). That diversity doesn't only have to come in the form of a classroom layout. Diversity can come with materials, lighting, and physical features that inspire the students in different ways. OWP/P et al. also talk about how important acoustics and daylighting are to the success of students, saying that using absorbent materials allows teachers to focus on teaching and not repeating. They also point out that increasing daylight shows a decrease in absenteeism and an increase in test scores (p.43 and 47). If these two simple changes in the architectural design of classrooms can have that large of an impact with students and instructors, why is it not being done on a more consistent basis?

In essence, how can we design flexible spaces to apply multiple learning methods/styles and how does that affect student learning?

BACKGROUND INFORMATION

To aid in the development of the research and design solutions of the project, a philosophical framework was determined. Deductive reasoning will be used to determine the cause and effect of different architectural layouts or features and their relationship to the performance of students and instructors. Many factors will work together simultaneously to inform the performance through an inductive process as well. Intersubjective epistemology and ontology will help to understand sociocultural engagement and the diverse realities situated in that context of architectural spaces. Internal validity and credibility will help correlate data and inform the design of the learning environments in real world applications.

With the results of running the designed classroom simulations, the data collected compared to the standards set forth by the research should provide insight into what recommendations can be made for educational facility implementation. If the designed spaces do not meet the standards, studying the data should inform why they did not meet the standards and how they can be changed to do so. The main focus of this research is to understand how we can improve learning environments through architectural means.

DISCUSSION OF PROCEDURE:

General Methodology and Research Methods

This study will use experimental and simulation strategies to create, test and conclude/analyze the data to understand and explain how a variety of learning spaces improve student learning. Causal comparative studies, as defined by *Architectural Research Methods* by Groat and Wang, will be used to select comparable classrooms and learning environments and collect data on a variety of select variables. Based on the research obtained, the development of classroom designs and then using software programs to analyze each variable will provide the data necessary to correlate with recommended levels.

Based on learning methods and researched environmental factors, Revit will be used to create these learning spaces / layouts to show how each space is used differently and how certain variables affect student learning. From there, the learning environments will be tested using Ease, Simulation CFD, and Insight, a Revit plug-in, to determine the values that can be used to evaluate the success or failure of the classroom layouts. That design will include a variety of variables such as Lighting levels, Thermal/HVAC levels, and Acoustical levels. The data taken from the evaluation of the spaces by the above software's will then undergo cross-checking against the recommended levels obtained in the research. If the environments do not meet the standards found in the research, conclusions will be made to adjust the environments to achieve the recommended levels.

RESULTS

Insight 360: Studying the Effects of Lighting Levels in the Classroom

The first step was creating the classroom layouts in Revit. After further review of the research and resources, it was determined that creating several basic classroom layouts with a few different lighting layouts and fixtures was important. The results gained from the simulations could then be easily compared to the researched standardized levels, providing a simple conclusion to the success or failure of each space and what individual elements were successful or unsuccessful. In the end, those features could be combined to conclude the most successful option for a typical classroom design. The following are the results of three lighting simulations.

After running the simulation, one particular value produced by the test was Lighting Efficiency. While this research does not intentionally include comparing costs of lighting, there is a direct correlation between lighting efficiency and cost. Lighting efficiency is determined by Lighting Power Density (LPD), which units are watts per square foot (w/ft^2). According to ASHRAE, the recommended standard for a classroom setting is 1.1 w/ft^2. Using Revit and Insight, it was possible to determine the watts per square foot of each space and the cost associated with that efficiency. From there, each space could be analyzed to see if it was meeting that standard or not.

Test #1 Results

1.14 w/ft^2 with 16 64-watt lighting fixtures at a cost of $2.72 dollars/ ft^2

Test #2 Results

2.84 w/ft^2 with 16 160-watt lighting fixtures at a cost of $2.53 dollars/ ft^2

Test #3 Results

2.13 w/ft^2 with 12 160-watt lighting fixtures at a cost of $2.69 dollars/ ft^2

It is evident through these simulations that the first test had the best results with a number nearly exactly the same as the recommended standard. This test was also completed with a standard, punched opening for a natural lighting source. Assuming that with a larger influence of natural light, the amount of fixtures could go down and receive the same amount of wattage per foot squared.

In a perplexing comparison, Test #3 removed four fixtures, reducing the wattage per foot squared but increasing the price by $0.16 per foot squared. It is unsure if this unexplained phenomenon occurred due to an error by the investigator or if there is an unknown factor at play, however interesting nonetheless.

Ease: Studying the Effects of Acoustics in the Classroom

Similarly, the first step was creating the classroom layout, only this time in a different format. Ease reads information in a different way than Insight, a Revit plug-in, does. For example, Ease reads information, such as a wall, as a collection of surfaces rather than a volume or physical construction of the wall. Therefore, the classroom needed to be developed as surfaces in SketchUp or a simplistic modeler that models in edges and surfaces.

Ease was found to be a difficult program to read complex forms and materials. The software runs simulations of acoustics by bouncing sound off of all the surfaces within a given volume, making it quite complex if large amounts of furniture and other items are within that volume. For the sake of this research, it was determined that running the simulation on a basic classroom setting could provide a benchmark to compare to the acoustical standards provided in the research. From there, it could be determined what changes would need to be made to meet those standards, if any.

After running the simulation, it was paramount to acknowledge two values: the average decibel level over the time period and the average reverberation time during the same period. The average decibel levels were supplied in both direct sound pressure level and total sound pressure level (SPL). The average reverberation times were simply given in standard seconds. That data could then be compared to the educational sound level standards from the Acoustical Society of America.

Direct SPL: The average decibel level of a period of 4 seconds was 73.99 db.

Total SPL: The average decibel level of a period of 4 seconds was 81.37 db.

The average reverberation time over a period of 4 seconds was 0.33 seconds.

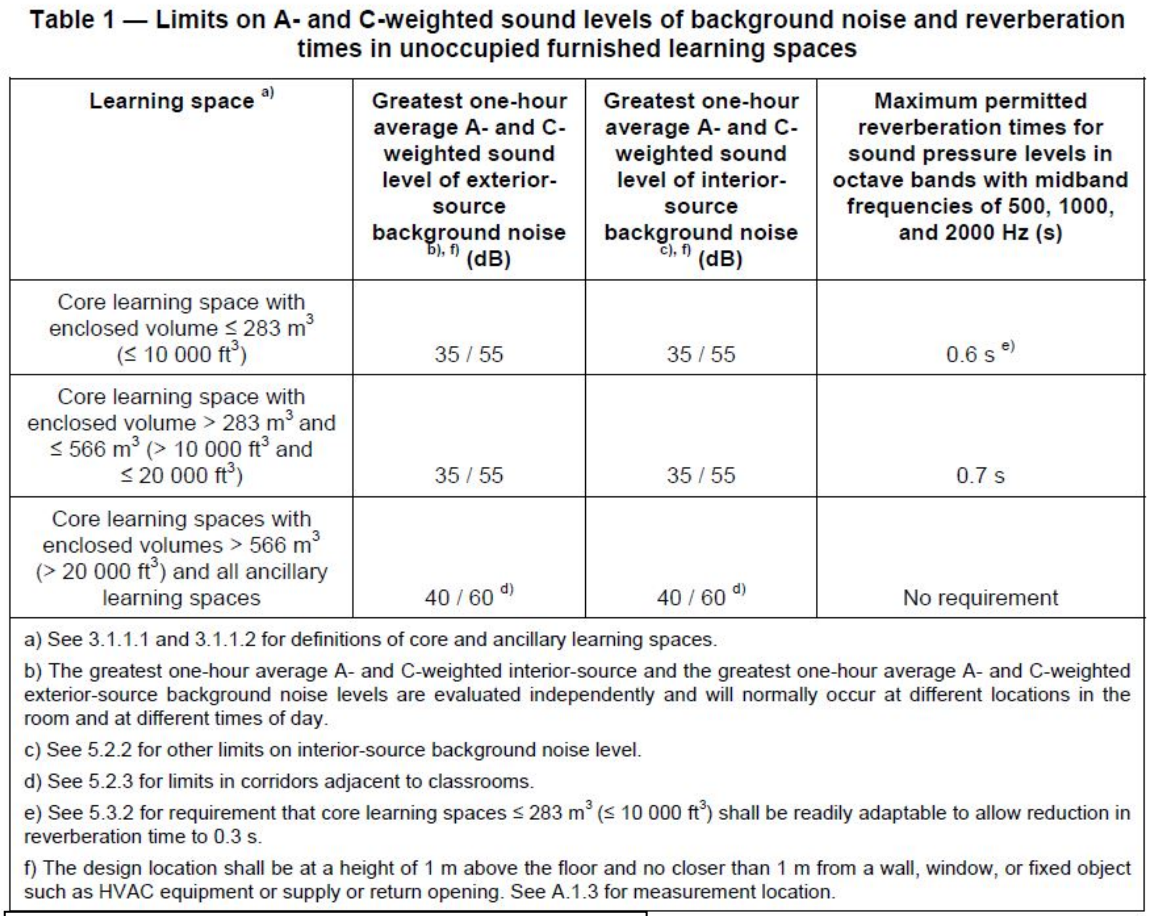


Table 1 — Limits on A- and C-weighted sound levels of background noise and reverberation times in unoccupied furnished learning spaces

Learning space a)	Greatest one-hour average A- and C-weighted sound level of exterior-source background noise b), f) (dB)	Greatest one-hour average A- and C-weighted sound level of interior-source background noise c), f) (dB)	Maximum permitted reverberation times for sound pressure levels in octave bands with midband frequencies of 500, 1000, and 2000 Hz (s)
Core learning space with enclosed volume ≤ 283 m^3 (≤ 10 000 ft^3)	35 / 55	35 / 55	0.6 s e)
Core learning space with enclosed volume > 283 m^3 and ≤ 566 m^3 (> 10 000 ft^3 and ≤ 20 000 ft^3)	35 / 55	35 / 55	0.7 s
Core learning spaces with enclosed volumes > 566 m^3 (> 20 000 ft^3) and all ancillary learning spaces	40 / 60 d)	40 / 60 d)	No requirement

a) See 3.1.1.1 and 3.1.1.2 for definitions of core and ancillary learning spaces.

b) The greatest one-hour average A- and C-weighted interior-source and the greatest one-hour average A- and C-weighted exterior-source background noise levels are evaluated independently and will normally occur at different locations in the room and at different times of day.

c) See 5.2.2 for other limits on interior-source background noise level.

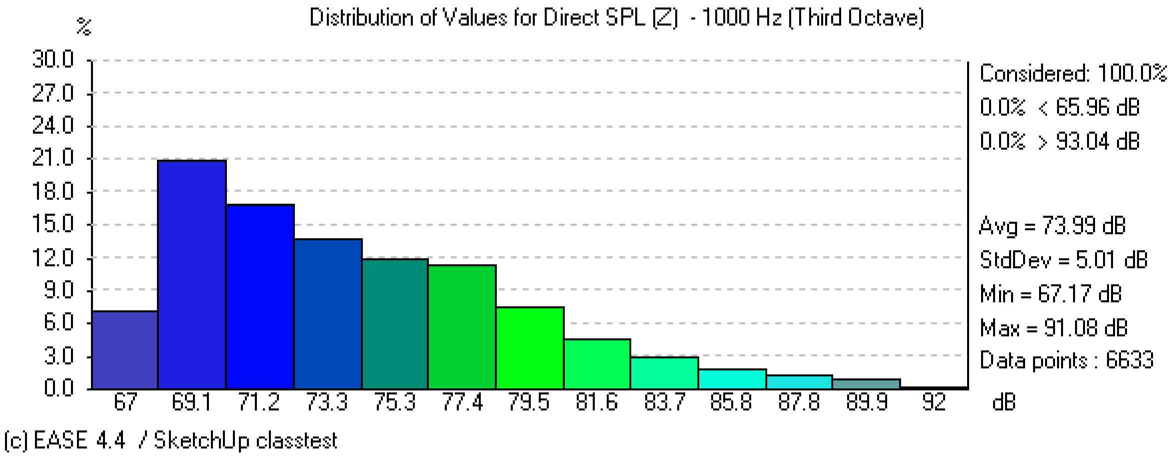
d) See 5.2.3 for limits in corridors adjacent to classrooms.

e) See 5.3.2 for requirement that core learning spaces ≤ 283 m^3 (≤ 10 000 ft^3) shall be readily adaptable to allow reduction in reverberation time to 0.3 s.

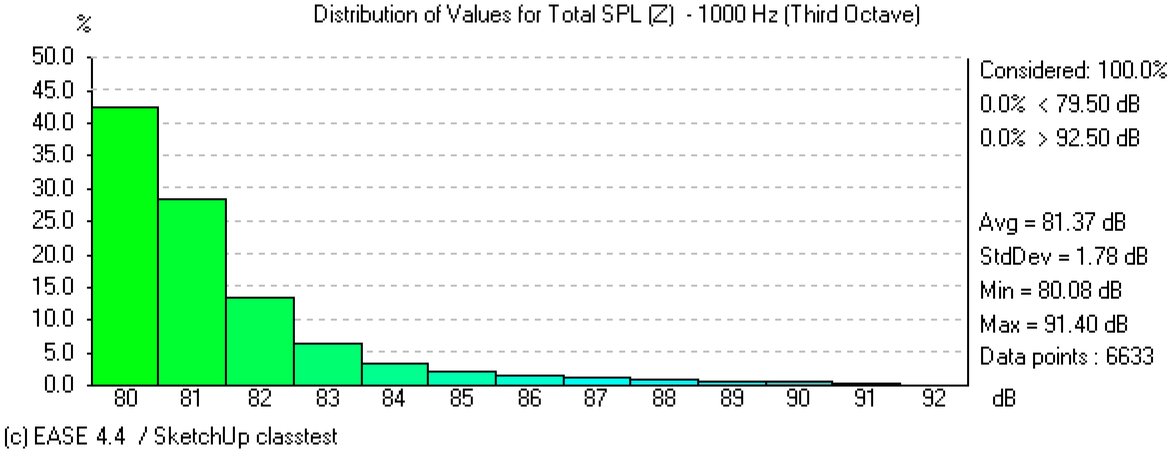
f) The design location shall be at a height of 1 m above the floor and no closer than 1 m from a wall, window, or fixed object such as HVAC equipment or supply or return opening. See A.1.3 for measurement location.

Figure 01, Acoustical Society of America

As you can see, these decibel levels are extremely high compared to the recommended levels. The downfall to these results, however, is that they are over a sample size of four seconds, whereas the standards are a recommended average of an hour. While this essentially makes the results inconclusive, they can still be used as a comparison. The averages were 73.99 and 81.37, which is still extremely high compared to the recommended levels. An interesting figure that was also discovered was the Distribution of Values for both the direct and total SPL levels.



This graph shows the distribution for the Direct SPL. It breaks down the decibel level traveling directly from the sound source to the listener over the period of time into percentages. In this case, 21 percent of the time the decibel level was at 69.1 db. This shows that for the largest percentage, the sound level was near the decibel level of a normal conversation.



This graph shows the distribution for the Total SPL. It paints a slightly different picture than the Direct SPL data. For about 42.5 percent of the time, the sound level was at 80 db. This is much too high for a student learning environment.

Autodesk CFD: Studying the Thermal Properties in the Classroom

In this case, CFD works together with Revit to provide an analysis of the thermal properties of the classroom. However, the process discovered some disadvantages to the program, and inevitably, the decision was made to abandon this portion of the simulations. One motive for this decision was the software itself. For being a program designed to work with Revit, its cooperation with it was very limited. CFD reads the geometry from Revit, but it doesn’t import materials. In order for the simulation to be successful, all volume and surface materials must be set to give the simulation all the necessary components, but to manually input all of these materials is a serious time commitment and downfall to the software.

It was also concluded that with today’s HVAC systems, the thermal environments and properties within educational facilities can be monitored, altered, and set to standards set forth by educational resources. It was deemed to be more significant to focus on the aspects of classroom design that have a direct impact on the students and the learning processes, such as the ones outlined earlier in this article.

CONCLUSIONS & IMPLICATIONS OF PRACTICE

In the case of simulations run with the program Insight 360, a few conclusions can be made following obtaining the results. The first test performed quite well, displaying data that was on target with the standards recommended by the ASHRAE standards. The other tests were not successful, showing an unnecessary amount of wattage per foot squared. While it was successful in producing the wattage per foot squared, it seems as though the results were inconclusive. The simulation provided data on interior and exterior lighting levels, but not a combined calculation. This is an important factor that is missed in this study. OWP/P et al. state that letting the daylight in is one of the most significant design aspects in classroom design. Daylighting and artificial lighting must combine and work together to provide the satisfactory levels for a student to be comfortable in their learning environment. If this research were to be completed again, it would be vital to use software that could create data points to demonstrate the combined levels of lighting in a classroom setting. Another aspect to the Insight data was the information gathered in Test #2 and Test #3. Test #2 had four more of the same fixtures than Test #3. While the second test had a higher watts/ft^2, which was to be expected due to the increase in fixtures, the third test had a higher cost per square foot. This didn’t seem to fit the expectations, so it is unsure what caused this result. Overall, the Insight 360 program was more of a design aid than an analytical tool. It allowed you to choose ranges in which you wanted your building to perform under, but it didn’t provide much data on the actual performance of the designed learning environment.

Another aspect that if changed could yield better results is that, for this simulation, only the classrooms themselves were created in Revit. A standalone classroom is unrealistic, and if it were to be designed as part of an entire educational facility, the results might be a little more conclusive. Testing a variety of spaces with that facility would give a larger spectrum of results as well. For instance, a public area may respond differently to lighting levels than a classroom would.

Reflecting back on the thermal properties section of this research, it was determined that thermal levels can be so closely monitored with advanced HVAC systems in today's facilities, that once the recommended levels have been established, the user simply applies those standard levels to their system. For instance, if the most comfortable temperature for a student learning environment is 72 degrees, the staff can set the HVAC to that specific degree and in turn that space will reflect that temperature. While those standards can be researched and discussed, there really wasn't a need for a simulation to be conducted concerning these levels in a classroom.

EASE Acoustic Software was not a user friendly program to use. Whether the computer running the program simply did not have the capabilities of running the software at maximum, or the program working inefficiently, it is unknown. The software was only able to handle simplistic environments with basic surfaces as the walls, floors, and ceilings. This restricted the possibility of creating a realistic scenario. In a real built environment, there are many factors that have a role in the decibel and reverberation of sound in a space. For instance, the amount and type of furniture in a space can have a significant impact on the sound levels of that space. Furniture may absorb much of the background noises in a classroom, or they could reflect great amounts of sound, depending on the materials. Likewise, if there are just a few pieces in the room versus an entire classroom setting, the results would be impacted as well. Other surfaces, such as white boards, tack boards, cabinetry, and projector screens, could have an impact on the sound levels of the space. It is true that the basic surfaces of a classroom setting provided a benchmark for what would need to happen to a space to ensure that the sound levels are within a healthy and comfortable range. However, in order to have realistic results reflecting a real learning environment, the space should have as many of the variables discussed above in order to have conclusive results.

Another aspect of the EASE software that was troubling to the results was the small sample size that the software is able to produce. While attempting longer trials of the simulation, the software would bog down and be unable to establish impacts of sound rays throughout the space. The most successful time period was four seconds. It has become apparent through the research of this project that sound is not static in nature; it varies and changes as it moves through a space. The capability of running a simulation for a longer period of time would suggest how that sound changes over time. Also, the standards recommended by the Acoustical Society of America were averages taken over an hour of time. While it provides an idea as to how sounds responded in the space, the results do not reflect what would happen over a longer period of time. One can speculate by using the distribution of sound levels and seeing that the levels decrease over the four second period that the same would happen over a time period of an hour, but without being able to test that variable, the results are inconclusive. If the simulations were to be further investigated, it would be paramount to match the variables of the simulation to the variables of the recommended levels by the various agencies.

Overall, much knowledge and understanding of lighting and acoustic levels has been obtained. This knowledge will be of vital importance in future design projects and understanding how to develop learning environments to be the most supportive and successful for its students, teachers, and staff.

REFERENCES

Acoustical Society of America (2015). American national standard acoustical performance criteria, design requirements, and guidelines for schools, part 1: permanent schools. Retrieved on December 15, 2015, from Acoustical Society of America: http://asastore.aip.org/

ASHRAE. (n.d.). Advanced energy design guide for k-12 schools. Retrieved December 15, 2015, from ASHRAE: https://www.ashrae.org/File%20Library/docLib/Special%20 Projects/AEDGPresentations/AEDG-K-12-Schools-Webinar-Trng-DOE-Jan09.pdf

Gardner, H. (2006). Multiple intelligences: New horizons (Completely rev. and updated. ed.). New York, New York: BasicBooks.

OWP/P Architects, VS Furniture, & Bruce Mau Design. (2010). The third teacher: 79 ways you can use design to transform teaching & learning. New York, New York: Abrams.