How does Architecture Affect the Acoustics of a Space

Grade Level
This lesson plan was developed for a 9th grade Physical Science Class.

Objectives
- To develop aural senses of spatial awareness
- To understand how the dimensions and material composition of a space affect acoustics

Key Ideas
Architectural Acoustics is the science of controlling the sound in spaces. Many of the members of this field have a background in architecture, engineering, music, and physics. (Acousticians can train at 5 or 6 masters in Architectural Acoustics in the country; and there are undergraduate programs throughout the country including one at the University of Hartford.)

Factors affect the acoustics of the space:

- **Reverberation:** In an enclosed space, when a sound source stops emitting energy, it takes some time for the sound to become inaudible. This prolongation of the sound in the room caused by continued multiple reflections is called reverberation.
    - Reverberation time is effected by the surfaces in the room and the shape of the room.
    - A space with a number of reflective materials will have a longer reverberation time.
    - A high reverberation time causes the build-up of the noise levels in the space.
    - Absorptive surface treatments can help to eliminate reverberation problems.
- **Reflection**: Sound waves often strike many surfaces before reaching the listener.
    - Reflections can be attributed to the shape of the space as well as the material on the surfaces.
    - Domes, peaked ceilings, reflective corners and concave surfaces cause reflections to be focused rather than dispersed that can create a "megaphone" effect potentially causing annoying reflections and loud spaces.
    - Absorptive surface treatments can help to eliminate reflection problems.
- **Absorption**: a means of solving problems of reverberation and reflection. The measurement of the Noise Reduction Coefficient (NRC) goes from perfectly reflected (0.00) to perfectly absorbed (1.00)
    - Hard surfaces like plaster, glass and painted concrete reflect ("bounce") sound
    - Carpeting, drapery and acoustic tiles absorb sound

Material	NRC
Brick, painted	.00 - .02
Brick, unpainted	.00 - .05
Carpet, indoor-outdoor	.15 - .20
Carpet, heavy on concrete	.20 - .30
Concrete, painted	.00 - .05
Concrete, unpainted	.00 - .20
Cork, floor tiles (3/4" thick)	.10 - .15
Cork, wall tiles (1" thick)	.30 - .70
Drapery, light weight (10oz.)	.05 - .15
Drapery, medium weight (14oz.), velour draped to half	.55
Drapery, heavy weight (18oz.), velour draped to half	.60
Glass	.05 - .10
Linoleum on Concrete	.00 - .05
Marble	.00
Plaster	.05
Plywood	.10 - .15
Seating (occupied)	.80 - .85
Seating (unoccupied), metal or wood	.30
Seating (unoccupied), fabric upholstered	.60
Steel	.00 - .10
Wood	.05 - .15

What does the function of the space do to its acoustical needs?

- Some spaces need to be quiet to function properly like libraries & museums.
- In some spaces, the function requires that a speaker be heard clearly like in lecture halls and classrooms.
- For some spaces, there is the need to keep sound within the closed room like in counseling offices.

What mitigating factors effect the use of acoustically sound materials?

Funds—sometimes the most acoustically sound material is too costly
Function—for example, sometimes the space has multiple functions and so it is hard to create a space that is acoustically optimum

Acoustics in the John Hay building:

- Particularly acoustically sound spaces:
    - New Media Center

    - Auditorium
    - Band Room
- Spaces with some acoustic quirks/reverb/reflection:
    - hallways (but the length and the number of openings improve the acoustics considering the ceilings and plaster)
    - pool

Procedure

1. Begin with questions that elicit students to reconstruct what they have learned about sound and light waves throughout the unit. Write the major themes from the unit on the board.
2. Lead a discussion where students discuss the key themes of acoustics in regards to the same CMA images.
3. Tell the students today they will be gauging the acoustic quality of different spaces in the building. Explain the main factors in architectural acoustics.
4. In each space, students should first note the function of the space and work as a team to write down all of the materials in the space (including furniture). Then one student will stand across the room from the other three students and read from a predetermined (and undisclosed) list of words. (The distance between the reader and the students will be marked prior to the activity)
5. The students will rotate through the building to all of the spaces listed on the graphic organizer.
6. After all of the data has been collected, students will correlate the words that were read in the space with the words that were heard.
7. They will work as a group to write out laboratory findings. In which spaces were the most words misheard? What materials were in that space? In which spaces were the words most clearly heard? What materials were in that space?
8. For homework, students will use the findings in the laboratory to decide how acoustically sound is the space depicted in the Cleveland Museum of Art's painting *Interior of the Pantheon*.

Assessment

Completion of the laboratory
Completion of the homework

Enrichment

Have students calculate the Calculation of the Sound Field in their bedroom using the calculator on http://www.whyverne.co.uk/acoustics/Pages/cismslow/cism.htm

Noise Reduction Coefficients (NRC) of Common Building Materials

Material	NRC
Brick, painted	.00 - .02
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Carpet, indoor-outdoor	.15 - .20
Carpet, heavy on concrete	.20 - .30
Concrete, painted	.00 - .05
Concrete, unpainted	.00 - .20
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Architectural Acoustics Graphic Organizer

Name of the Space	What is function of the space?	What is the shape of the space?	What materials is the space composed of? (Wood floors? Plaster walls? Acoustic panels? What else?) What are their NRCs	What sounds do you hear in silence?	What words do you hear when your partner speaks from across the room?
Dining Hall					
Band Room					
Auditorium					
Balcony of the Auditorium					

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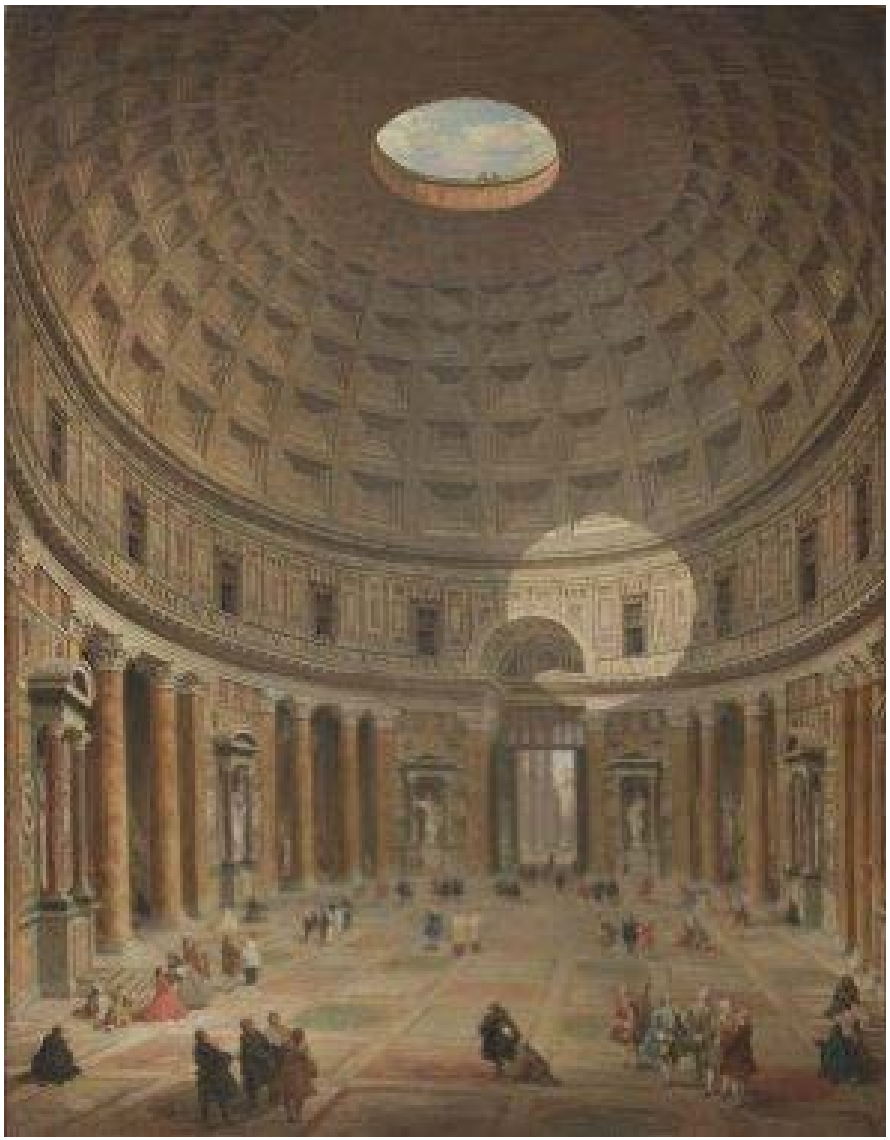
Hallway					
Pool					
New Media Center					

Summarize your findings:

In which spaces, did your group mishear the most words? What materials was the space composed of?

In which spaces, did your group hear the most words correctly? What materials was the space composed of?

The Annunciation, Albert Bouts (Netherlandish, 1451-55 - 1549) c. 1480
1942.635



Interior of the Pantheon, Rome, Giovanni Paolo Panini (Italian, 1691 - 1765) 1747
1974.39