

Bridging the Technology Divide in the COVID-19 Era: Using Virtual Outreach to Expose Middle and High School Students to Imaging Technology

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Abstract

Increasing the diversity of students choosing careers in science, technology, engineering, and mathematics (STEM) fields is an area of intense focus across the USA, especially in kindergarten through 12th grade (K-12)-focused pipeline programs in medical schools. A diverse STEM workforce contributes to better problem-solving and equity in health care. Two of the many major barriers for rural students are the lack of sufficient STEM role models and limited access to technology in the classroom. Medical schools often serve as an important resource for students in the local community who can easily gain access to STEM professionals and modern technology through on-campus, sponsored events and STEM outreach to the local classrooms. However, underrepresented minority (URM) students often live in socioeconomically distressed parts of rural states such as Arkansas, where access to STEM role models and technology is limited. Virtual learning in the COVID-19 era has proven that the imaging technology resources of a medical school can be harnessed to reach a wider audience, especially students living in rural areas far from the medical school campus.

Introduction

Medical school-sponsored K-12 pipeline programs for STEM exist because the low representation by underrepresented minorities (URMs) in the medical profession mirrors the lack of diversity in other STEM fields. The lack of diversity among researchers and health care professionals can contribute to health disparities. Many health care workers do not resemble

the patients they serve, which can leave the patients feeling excluded¹. Nationally, URMs represent 37% of the US population² but only account for 7%-10% of professional school faculties^{3,4,5}. The need for a diverse, culturally competent health care workforce is of primary importance in identifying, addressing, and eventually reducing health

disparities. Diversity in the health professions can address health disparities through research dedicated to diseases with a disproportionate impact on racial and ethnic minorities and by helping increase the number of physicians willing to serve in typically underserved communities⁶.

There are a number of factors that impede URM students from enrolling in and successfully completing STEM degrees. These barriers include a small applicant pool due to reduced rates of completion of high school⁷, significantly lower completion rates of STEM majors in college and obtaining of advanced master's or doctoral degrees⁸, less persistence in school^{9,10} and lower overall graduation rates¹¹, reduced exposure to high-level curricula and less qualified teachers in their communities¹², and even differences in preferred learning styles in school (e.g., URMs prefer small-group, hands-on activities vs. lectures)^{13,14}. It is well known that early educational encounters are extremely important in shaping the long-term educational experiences of URM students, who typically come from educational environments that are not supportive of, and are even indifferent to, minority students. Most URMs do not have a STEM role model in their extended family or even their local community. Recent studies have indicated that early exposure to STEM outreach programs is positively associated with establishing a STEM identity and seems to stimulate student interest in STEM^{15,16,17,18}.

As the only allopathic academic medical center in the rural state of Arkansas, which has one of the highest rates of poverty in the US¹⁹, the author's university and its Division of Diversity, Equity and Inclusion has, over the years, established a robust K-12 pipeline to support the recruitment of URMs into its programs. Mentoring students at an early age has been shown to be an effective strategy

in recruitment, retention, and graduation efforts. Pipeline programs at undergraduate schools across the nation have shown some successes in this regard (e.g., increased URM populations applying for medical schools⁶). Pipeline programs targeting middle and high school students have also shown some early signs of success^{20,21,22}. Early intervention efforts to stimulate student interest in STEM can lead to diversity in the students interested in STEM-related fields and careers, which can lead to an increase in the number and diversity of high school students who enter college, choose a STEM major, and pursue a graduate degree in biomedical sciences and/or a health profession degree.

COVID-19 has caused many disruptions to K-12 education, including restrictions on access to medical campus facilities for middle and high school students and an interruption of in-person outreach visits to local schools. The pandemic has forced many STEM outreach providers to reimagine themselves from a paradigm design based on small-group, hands-on, focused approaches to one that involves virtual outreach^{23,24,25}. The challenges that accompanied this change included the loss of personal interactions, the loss of hands-on interaction with technology, the lack of students' ability to experience a visit to a medical school campus and its facilities in person, and fatigue with online learning platforms²⁶. These challenges can be partially offset by the opportunities of providing virtual outreach, which include a chance to broaden participation and bridge the technological divide through exposing students across the state to sophisticated imaging technology not available in their classrooms.

Medical schools are an important resource for advanced imaging technologies and other commercially available

educational technologies that are beyond the normal budget of middle and high school classrooms. Ultrasound is an excellent imaging modality for middle and high school students because it allows for peering inside the human body in real time. This can be very engaging for students, even when the presentation is virtual. In the USA, national science standards include learning about the properties of waves in middle and high school science classes²⁶. Demonstrating ultrasound and its use in medical imaging is a great way to tie the outreach session to classroom lessons. Nothing can capture the attention of students more than the live scanning of a person's body, especially something that is moving—the heart, the contraction of a muscle, or peristalsis of the gastrointestinal tract. Access to X-ray and computerized tomography (CT) imaging technologies for STEM outreach events is not possible because of the high cost of the equipment, busy clinical use schedules, and safety issues.

Fortunately, there are different anatomy visualization imaging tables that are becoming widely available as a resource on medical school campuses²⁸. These tables have databases of CT images obtained from real human patients that can be shown to students, including with 3D reconstruction capability. Middle and high school students will also be familiar with the electromagnetic spectrum (e.g., X-rays, light, infrared), which is included in the national science standards, so the use of this type of imaging technology again ties quite nicely into what they are learning in the classroom. Access to medical-quality electroencephalography (EEG) equipment for use in virtual STEM outreach events is difficult even in the medical school setting and would require skilled staff to prepare the subject for EEG recording. Relatively low-cost, commercially available headsets might not be available to individual middle or high school classrooms but are certainly within the realm of a medical school STEM outreach budget.

These commercially available wireless headsets require minimal time to set up and offer software packages that allow for visual imaging of the EEG activity in the brain, which is ideal for the middle and high school target audience that is unfamiliar with this brain activity imaging modality.

Conducting effective virtual STEM outreach sessions requires more than a laptop computer, a camera, and a web-based video platform. The basic desktop or laptop computer will need to be supplemented with a variety of other equipment to enhance the experience and provide a high-quality, professional-looking broadcast. This paper describes an integrated three-station approach that has been used to provide synchronous, web-based, virtual outreach activities that include advanced imaging such as ultrasound and CT imaging, as well as the visualization of EEG activity localization in the brain.

Protocol

This study was approved by the institutional review board as belonging to an "exempt" status category, and, as such, the program evaluation data collected from the students and teachers did not require consent. The ultrasound and electroencephalogram recordings outlined below were conducted on standardized patients (SPs) with full understanding that this was part of an educational outreach event.

1. Equipment positioning and connections

1. Broadcast laptop computer
 1. Position the laptop computer (**Figure 1A**, thick red arrow). on a centrally located table serving as the broadcast studio central station. Plug the charger of

the laptop into a surge protector so the laptop is fully charged for the entire outreach event.

2. Plug the universal serial bus (USB) cable of a high-quality microphone condenser microphone into the USB port of the laptop or use a multiport USB extender if needed.
2. Video switcher for video input selection and picture-in-picture (PIP) capability
 1. Plug the power cable of the video switcher (**Figure 1A**, thick green arrow) into a surge protector and attach the other end of the power cable to the "power" plug on the video switcher.
 2. Plug the USB cable to the "USB out" port of the video switcher and plug the other end into the USB port of the broadcast laptop.

NOTE: The USB out of the video switcher essentially acts as a webcam and should be recognized as such by web-based video platforms.
 3. Plug the video switcher-supplied ethernet cable into the ethernet port of the video switcher. Plug the other end of the cable into a USB3.0 to Gigabit Ethernet Adapter and then plug the USB end of the adapter into another USB port of the broadcast laptop or use a multiport USB extender if needed.
 4. Download the video switcher software on the dedicated broadcast laptop using the link supplied by the company.
 3. Tripods and overhead rig for video camera mounting
 1. Position an overhead modular studio rig over the anatomical specimen station with a large table positioned underneath (**Figure 1B**). Attach and center an adjustable camera mount to the overhead

rig (**Figure 1B**, red arrow) so that it is centrally located over the anatomical specimen station. Mount a high-quality video camera equipped with remote control onto the camera mount (**Figure 1B**, blue asterisk). Plug the camera power cable into the camera power port.

2. Strategically position sturdy, adjustable tripods in the broadcast area (**Figure 1A** and **Figure 1C,D**, blue arrows). Position one main camera for wide-angle views at each station. Position any additional cameras for close-up views at the various stations (e.g., ultrasound station to show probe placement on the standardized patient [SP]).
3. Mount a high-quality video camera on each tripod (**Figure 1A** and **Figure 1C,D**, blue asterisks). Plug the compact power adapter into a nearby outlet and the other end into the charging port of the camera. Attach a lens hood to block stray light from ceiling lights.

NOTE: Although most video cameras come with battery packs, it is wiser to use power cables so that the camera does not unexpectedly lose power during a broadcast. The remote control capability of the overhead camera allows for easy adjustment of the zoom feature without having to block the live video feed inset view by standing in front of the anatomical specimen station. The presenter or another staff member can adjust from a distance.
4. Plug a mini HDMI to HDMI cable into the mini HDMI port on each camera. Plug one end of an extra-long HDMI cable (e.g., 15 ft long) into the mini HDMI cable. Position the HDMI cables to run toward the video switcher.

5. Position the HDMI cables in the room to enable easy movement and tape them onto the floor to prevent tripping. Wrap the HDMI and power cables attached to the camera mounted on the overhead rig around the rig structure so that they are not in view of the main station camera and do not fall down during the broadcast.
4. Multiport HDMI switcher
 1. Connect those video cameras selected to provide video feed for the small inset in PIP mode to a multiport HDMI switcher equipped with a remote control (**Figure 1A**, thin green arrow).

NOTE: A multiport HDMI switcher will be necessary if the number of HDMI input devices exceeds the maximum of four HDMI ports available on the video switcher.
 2. Connect the output HDMI of the multiport HDMI switcher to one of the four main HDMI inputs on the video switcher.
5. Secondary laptop computer for slide presentations and serving as the wireless interface to the EEG laptop
 1. Connect the secondary laptop computer (**Figure 1A** and **Figure 1C**, thin red arrow) to its power charger and plug this into the surge protector.
 2. Connect one end of an HDMI cable to the HDMI port on the laptop and the other end to one of the HDMI inputs on the video switcher.
 3. Charge up a wireless remote control and plug the USB receiver into one of the USB ports of the secondary laptop computer.
 4. Preload any slide presentations onto the desktop of the presentation laptop.

NOTE: The use of customized "welcome slides" will personalize the virtual presentation.

6. Broadcast monitors
 1. Strategically position laptop computers on a chair/stool near each station to be used as broadcast monitors (**Figure 1A-C**, yellow arrows). Plug the laptop charger into the surge protector.

NOTE: These monitors are required so that the presenter can observe the broadcast just like any participant. This capability is especially important at the anatomical specimen station to be able to adjust the position of the specimens on the screen.
 2. Activate the wireless internet connectivity of the laptop so that it is ready to use.
7. Ultrasound scanning station setup
 1. Position a clinical ultrasound laptop device and a laptop cart in a central region of the ultrasound dedicated station (**Figure 1A**, purple arrow). Plug the power cord of the ultrasound device into a surge protector.
 2. Connect an HDMI cable to the HDMI port of the ultrasound laptop computer and the other end to the HDMI input of a signal Converter device. Connect one end of an HDMI cable to the HDMI output of the Converter and the other end to the video switcher or HDMI switcher.
 3. Set the built-in switches of the Converter to reconfigure the HDMI output of the ultrasound laptop to match the HDMI input requirements of the video switcher. In this instance, the settings were **1,2,3,4,5,7 = On; 6,8 = Off**.

NOTE: Converter settings for specific brands of ultrasound laptop systems may need to be determined through trial and error.

4. If an electrocardiographic (ECG) package is an available option for the ultrasound laptop device (e.g., a three-lead USB-ECG unit), plug the USB end into the ultrasound laptop. Place the three ECG snap electrodes near the device ready to apply to the SP.
5. Strategically position a patient stretcher or portable massage table so that it lies at an angle to the main view of the camera dedicated to the ultrasound (US) station (**Figure 1A**). Place a bed cover on the table and position the patient pillow with the pillow cover at the end closest to the US cart. Place a bottle of ultrasound gel and paper towels within arm's reach so that they can be used to conveniently wipe the gel off the SP.
8. 3D anatomy visualization table station setup
 1. Plug the power cable of the anatomy visualization table into a surge protector and turn on the table. Plug the ethernet cable of the anatomy visualization table computer into a wall-mounted, active ethernet plug or log the table into wireless internet.
 2. Plug one end of an extra-long HDMI cable (e.g., 15 ft) into the anatomy visualization table and the other end into one of the HDMI ports of the video switcher or the HDMI switcher.
 3. Log into the anatomy visualization table using the credentials supplied by the company. Preload one of the relevant CT cases for the planned session (e.g., a heart bypass surgery case) and position it to the right of center so that it is not blocked by the PIP inset.
9. Electroencephalographic station setup
 1. Plug the charger cable supplied with the wireless EEG headsets into the headset and plug the other end into the USB port of a computer to fully charge the headset. Plug the wireless Bluetooth adapter into the USB port of the computer or use a USB adapter to fit the laptop.
 2. Once the headset is fully charged, insert the foam caps into each of the 14 leads on the EEG headset and apply a few drops of saline eyedrop solutions to each lead. Position the headset onto the SP's head and adjust the position of the leads as directed by the headset instructions. Turn on the headset using the button on the headset.
 3. Turn on the EEG-dedicated computer and activate the wireless EEG headset software. Select the available headset device, choose **connect**, and follow the instructions in the software until all the lights are green on the headset image, indicating proper contact of all 14 leads. Click on the wireless headset software link at the top left of the window to switch screens to the live EEG recordings. Adjust the settings as needed.
 4. Activate the EEG brain visualization software. Select the same available headset and choose **connect**. Click on the **icon** located at the bottom frame of the window and select the overhead **stationary view** of the brain.
 5. Reduce the size of the brain visualization and EEG software windows so that each takes up half of the desktop on the laptop screen.

6. Turn on **screen sharing** for the EEG dedicated laptop (e.g., **System Preferences | Sharing | Screen Sharing ON** [with all users selected]).
7. Connect both the EEG-dedicated and slide-dedicated laptops to the same wireless network. On the slide-dedicated laptop, install and activate the remote desktop viewer software by clicking on the appropriate icon on the desktop. Connect to the EEG-dedicated laptop by entering its name or IP address into the **Remote Host** box and then click on **Connect**. Sign in to the EEG-dedicated laptop using the shared screen that appears on the slide-dedicated laptop.

2. Testing the web-based video platform broadcast settings, video equipment, and software connections

1. Broadcast laptop

1. Open the web-based video platform program on the broadcast laptop and start a **new meeting** session.
2. Click on the arrow to the right of the **Mute** icon on the bottom left of the video platform program screen border. Under the **Select a Microphone** list, choose the **accessory microphone**. Press the **test speaker and microphone** choice to test the audio out and audio in sound levels.
3. Click on the arrow to the right of the **Stop Video** icon at the bottom of the video platform program screen border. Under the **Select a camera** list, choose the video source that is listed as **1920 x 1080_60.00fps**.
NOTE: The video switcher input to the laptop will appear as two separate listings (one at 60 frames/s and the other at 30 frames/s).

4. Select the **Stop video** pull-down menu | **video settings**. Under **camera** settings, uncheck **mirror my video**.
5. Click on the **participants** button located on the lower border of the video platform program, and then click on the **invite** button on the bottom of the right panel. Copy down the **11 digit meeting number** and the **6 digit Meeting Passcode number**, which will be needed in step 2.3.1.

2. Video cameras

1. Test the main camera views at each station by pressing the corresponding button on the video switcher or the multiport HDMI switcher. Make sure everything is centered in each view.
2. Test the PIP setup for each camera designated as a PIP camera by selecting the camera on the video switcher and selecting the PIP mode on the device. Push the **PIP** button on the video switcher to activate the **PIP** mode.
3. Test the wireless remote to confirm easy switching between the cameras or other input devices attached to the multiport HDMI switcher.

3. Monitor laptops

1. Activate the web-based video platform program on each monitor laptop. Input the **meeting invite number** and press **enter**; input the **passcode number** and press **enter**. Close the window that asks to join audio but **do not join audio** to avoid audio feedback.
2. Select the **Stop video** pull-down menu | **video settings**. Under **camera** settings, uncheck **mirror my video**.

NOTE: The monitor for the anatomical specimen station with the overhead camera must have settings that match the broadcast laptop video camera settings to ensure that the orientation of the specimen is the same for the presenter as for the students.

3. Click on the **monitor** icon in the video platform program and rename the laptops as **Monitor #1** and **Monitor #2** so that the participants will know that it is not another attendee.
4. Select **Speaker view | Full Screen**. Pin **speaker view**. Reduce the inset by pressing the first - button. Move this off to the side of the screen so it does not block any view.
4. Presentation laptop and remote
 1. Turn on the slide-dedicated laptop. Change the window settings to duplicate the display (i.e., **windows settings | system | multiple displays | duplicate these displays**).
 2. Activate the slide presentation program and load a test file. Select the **slideshow** icon and test the remote slide advancer to check if it works from where the presenter will be standing during the session.
5. Video switcher software control settings
 1. Construct a flow chart for the session that includes a list of shots with the specified camera view, its video feed source, and whether it will include PIP mode. Ensure that the list includes the exact placement of the inset depending on what source is filling the main part of the screen (i.e., offset to the left or upper-left corner) (e.g., see the screenshots in **Figure 2A-I**).

2. Activate the video switcher software control on the broadcast laptop. Click on the pull-down menu for **Macros**. Move the popup window off to the side (see **Figure 1D**, single yellow asterisk).
3. Click on the **create** button on the macro popup window. Click on the **first empty slot** in the panel and then click on the **+** button. Type in a **name** for this first **shot** and then click on the **record** button.
4. On the **video switcher software control** panel, select the **Program** button for the appropriate camera (e.g., CAM1 or CAM4). If the shot does not have a PIP, go to step 2.5.7.
5. If the shot has the **PIP** mode active, click on the **ON AIR** button in the **Next Transition** section. On the right side of the screen, go to the **Upstream Key 1** section and click on the **DVE** tab. Select the **camera** in the **inset view** of the **PIP** mode as the **Fill Source**.
6. Change the **size** of the inset view by typing in the x and y positions and sizes. Confirm the position of the inset on the video platform program broadcast window.

NOTE: Clicking on the **X** or **Y** in either the **Position** or **Size label** section and moving the mouse left or right will scroll through the settings.
7. Click on the **Macro** popup window and hit the small red button to **stop** the recording.
8. Repeat steps 2.5.3-2.5.7 to create separate macros for each shot in the flow chart created in step 2.5.1 (e.g., see the screenshot shown in **Figure 1D**).

NOTE: The video switcher offers various video effects for transitions and lower thirds options for overlays. Only the basic operations for PIP mode are described in this protocol.

9. Click on the **File** pull-down menu at the top of the screen and choose **Save As**. Type in a **name** for the file settings.
6. Standardized patient
 1. Position the shirtless, male SP on the table. Position the cardiac ultrasound probe on the chest wall in the left 3rd or 4th intercostal parasternal space with the marker pointed toward the right shoulder. Adjust the probe until a parasternal long axis view of the heart is obtained demonstrating the left atrium, left ventricle, and aortic outflow tract and associated valves (e.g., **Figure 2E**).
 2. Attach the ECG pads to the SP (i.e., one above the right clavicle, one above the left clavicle, and one on the left side of the lower trunk). Attach the ECG leads to the pads, and test to make sure a stable ECG waveform appears on the ultrasound laptop device.

3. Live video platform broadcast session setup

1. Equipment check
 1. Start the video platform broadcast session whose link was sent out to the participants. Quickly check the microphone as in step 2.1.2.
 2. Redo steps 2.3.1-2.3.4 above to set up the monitor laptops.
 3. If there is a staff member serving as the chat bar monitor, have them send a welcome message to the participants in the chat bar telling them to send any anonymous questions to them so that they can share them.

NOTE: This is only necessary if students are individually logged into the session and can ask questions anonymously. Anonymity may help middle

to high school students who may not want to ask questions aloud in a virtual setting.

4. Advise the participants to switch to **speaker** mode to get the best experience.
 5. Start the video switcher software control program, click on the **File** pull-down menu | **restore**, and select the **file name** saved in step 2.5.9. Click on the **restore** button at the bottom of the new popup screen. Click on the **Macro** pull-down menu, and move the popup menu to the side. Click on the **RUN** button on the **macro** menu, and select the **first shot** from the **macro** menu.
 6. Move the video switcher software screen to the bottom, but leave some of the top white border available to click on when needed (see **Figure 1D**).

NOTE: Clicking on the video platform broadcast software window will result in the **MACRO** popup disappearing, but it will reappear after clicking on the video switcher software control window. This will need to be performed when checking the chat bar function.
 7. Start recording on the video platform software program to record the outreach session. Select the **record to this computer** choice.

NOTE: After the recording is stopped and the program is exited, a popup window will appear indicating that the software is **converting** the recorded video. This may take some time depending on the length of the virtual outreach session.
2. Anatomical specimen-specific content
 1. Heart specimen station
 1. Use sheep, pig, and cow heart specimens to demonstrate differences in heart sizes and the

relative size of the human heart (i.e., between sheep and pig hearts) (e.g., see **Figure 1B**). Demonstrate the pericardial sac in a sheep specimen and the surface anatomy of the heart using pig hearts.

NOTE: Human cadaveric hearts can be used in these demonstrations if age-appropriate for the target audience (e.g., upper-level high school students).

2. Identify the major blood vessels entering and leaving the heart using a heart model (**Figure 3A**). Demonstrate the location of the coronary arteries and discuss how blockage can cause a heart attack.
 3. Demonstrate the internal anatomy features of the heart (**Figure 2B**). Point to the four chambers and valves and mention their one-way function mediated by changes in pressure not electrical activity (**Figure 3A**). Point out the intrinsic pacemaker cells in the heart walls using a heart model.
 4. Mention the different thicknesses of the ventricular walls and talk about hypertrophy of the heart when it must work harder (e.g., during prolonged hypertension). Point out the interventricular wall and discuss babies being born with a hole in their heart (i.e., in the interatrial or interventricular septum).
2. Brain specimen station
1. Use a model to discuss the two main cell types that make up the nervous tissue in the brain (e.g., neurons and glia). Discuss the function of dendrites versus axons, how neurons connect

with each other at a synapse and that this is an electrochemical process, how glia wrap around axons to form myelin, and that multiple sclerosis is a disease that leads to demyelination.

2. Demonstrate the major portions of the human brain (i.e., cerebral hemispheres, cerebellum, brainstem) and contrast with the spinal cord. Point out the major fissure and gyri and sulci landmarks that characterize the surface of the cerebral hemispheres, such as the longitudinal fissure that separates the two cerebral hemispheres (**Figure 3B**, red arrow) and the central sulcus that separates the primary motor cortex and sensory cortex (**Figure 3B**, yellow arrow). Discuss the localization of function in the various lobes and the somatotopic arrangement of the primary motor and sensory cortex. Discuss the shrinking of the gyri in the brains of Alzheimer's patients.
 3. Demonstrate the major structures in a midline section of the brain (e.g., corpus callosum, thalamus, hypothalamus) and in coronal sections of the brainstem and forebrain. Point out the pigmented appearance of the substantia nigra and its importance in Parkinson's disease. Identify parts of the ventricular system and relate this to a ventricular full cast model.
3. Ultrasound station content
1. Basics of ultrasound
 1. Explain how ultrasound has a frequency higher than what humans can hear. Explain how the probes are the source of the sound and that the speed is determined by the medium it

is traveling through. Explain that US devices assume that the speed of sound in the body is 1,540 m/s but that different structures in the body have different conduction speeds. Explain that an echo in ultrasound is produced when sound travels from one medium to another and encounters resistance.

2. Orient the students to understand that the top of the ultrasound image is closest to the probe placed on the chest. Demonstrate B mode imaging of the heart in various planes of view (e.g., parasternal long axis and parasternal short axis) and point out the chambers and valves. Demonstrate color mode for imaging the flow of blood through the heart and explain that red means movement toward the probe and blue movement away from the probe.
 3. In the parasternal long axis view of the heart (e.g., **Figure 2E**), identify the mitral valve, which regulates the flow of blood from the left atrium into the left ventricle during diastole, and the aortic valve, which regulates the flow of blood from the left ventricle out to the aorta during systole. Show how the mitral valve alternates with the aortic valve and mention that the alternate closing of the valves produces the lub-dub of the heartbeat heard with a stethoscope.
 4. In the short axis view of the heart, identify the circular appearance of the left ventricle and the semilunar shape of the right ventricle. Angle the probe to visualize the aortic valve with the inverted Mercedes Benz sign.
4. Computerized tomography (CT) station content

1. Explain how CT scanners send X-rays through the patient in a spiral fashion allowing for 3D reconstruction in any plane. Use a case to explain the appearance of bone and metal (i.e., white) versus fluid (gray) and air (black) on CT images.
2. Select the multiplanar reconstruction (**MPR**) mode on the anatomy visualization table (i.e., click on the **blue man** icon | **MPR**) and choose each of the three major planes that will then appear in a panel on the left side. Double-tap the image to load it to the main screen and then double-tap again to reduce it. Demonstrate how the images scan through the body in different planes of view (e.g., coronal, sagittal, transverse).
3. For CT imaging of the heart, demonstrate the relative size of a normal-sized heart compared to the lungs (e.g., rule of thirds). Identify the four chambers of the heart, follow the aorta out of the left ventricle, and then identify the major branches of the aortic arch. Show an example of an enlarged heart with an implanted pacemaker (e.g., **Figure 2G**). Use this case to demonstrate an enlarged heart that occupies most of the left side of the thorax.
4. Show an example of a patient who has undergone open heart surgery as evidenced by the presence of metal wires holding the sternum together. Select the saved icon to demonstrate the occluded right coronary artery and identify and follow the coronary artery bypass grafts (one on the right and two on the left) that arise from the aorta and travel to the heart (see **Figure 3C**).
5. Electroencephalography station content

1. Show the wireless headset on an SP (inset, **Figure 3D**, yellow asterisk). Point out the 14 different leads (7 on each side) that are positioned over specific lobes of the brain. Discuss how the electrical activity of neurons and glia in the various lobes travel through the bone to the surface electrodes on the skin.
2. Turn the threshold up on the software to demonstrate that the entire brain is active. Reduce the threshold of the EEG waves in the wireless EEG software to demonstrate the localization of zones of high activity within specific lobes (e.g., frontal lobe and parietal lobe) (**Figure 3D**, left panel). Monitor the changes in activity in various lobes to demonstrate that there are general patterns of activity but that they are not repetitive each time.
3. Discuss how EEG activity consists of different waves with specific frequencies. Use the sliders on the brain visualization software window to isolate specific waveforms (e.g., alpha waves and beta waves). Have the SP chew to demonstrate movement artifacts of EEG recording or close their eyes to demonstrate the increase in alpha wave activity. Discuss the uses of EEG recording in a clinical setting (e.g., epilepsy or sleep studies).

Representative Results

A formal dedicated space for virtual broadcasts is not absolutely required and is limited by close access to the imaging technology. **Figure 1** shows a makeshift broadcast studio with all the equipment described in this protocol (**Figure 1A-D**). The main setup is located in a room that houses the anatomy visualization table (**Figure 1C**) and includes the ultrasound laptop device (**Figure 1A**), and

the adjacent hallway is used for setting up the anatomical specimen station to allow for the assembly of the overhead camera rig (**Figure 1B**).

Figure 2 includes sample video frame sequences from one of the heart-focused, virtual outreach sessions to demonstrate the types of screen formatting used to make the presentation visually appealing and enhance learning. Introductory information (e.g., a welcome slide, grant support, staff introductions, a brief session outline) is shown in a slide with a live presenter inset positioned off to the side (e.g., **Figure 2A,I**). This allows the presentation to be distinguished from regular slide presentations but maintains the video platform software feature of seeing the speaker.

Anatomical specimen demonstrations use a small presenter inset in the upper-left corner and the overhead camera as the main screen (**Figure 2B**). This allows the presenter to talk directly to the audience while demonstrating specific structures in a close-up view. Key point summary slides are shown as a simple slide alone, which enables the staff to move seamlessly behind the scenes from one station to another (**Figure 2C,F,H**) and helps students solidify main take-home messages. The strategically positioned monitors allow the staff to read the summary slide during the transition. The initial ultrasound view includes only a wide-angle view so that the presenter can introduce the SP, demonstrate the ultrasound laptop configuration, and introduce ultrasound and how the US probes work (**Figure 2D**).

An inset showing a closeup of the SP is included on the live US scanning since that helps students integrate what they are seeing with where the probe is being placed (**Figure 2E**). This is crucial for US since slight movements of the probe on the SP (e.g., rotating, sliding, or angling the probe) will change the resulting image. An inset is also used

when the anatomy visualization table is being demonstrated because seeing the table manipulation is key to orienting the students and understanding what is being shown on the 3D reconstructions (**Figure 2G**). This is extremely important when near-peer presenters (e.g., high school and college students) are used so that middle and high school students can imagine themselves one day being able to manipulate the technology.

Table 1 lists the video switcher software control key setting specifications used to generate the various frames shown in **Figure 2**. The table indicates the names of each user-defined soft button, which camera is activated for the main screen, which camera is used for the PIP view, and the size and position of the PIP inset. These settings are the ones generated in steps 2.5.1-2.5.8 listed in the protocol.

Table 2 lists the behind-the-scenes production notes that are used by the staff member managing the broadcast to know when to manually select the proper camera and advance the slides to get ready for the next shot. Although the video switcher enables smooth transitions between shots, someone still has to make some behind-the-scenes selections to make the broadcast appear seamless. In addition, even with the video switcher and the multiport HDMI switcher, the HDMI inputs from the ultrasound laptop HDMI input and the anatomy visualization table HDMI input need to be manually switched. This can be done while projecting a US summary slide.

If a second video switcher is available, the ultrasound and anatomy visualization table HDMI inputs can be plugged into the second video switcher and its output plugged into the HDMI port that is normally shared by the two devices on the main video switcher. In this instance, a simple button press on the second video switcher changes the input to the main video switcher without having to replace HDMI cables. The

ease of this arrangement may not be worth the added cost if the budget is limited. Alternatively, a second multiport HDMI switcher could be used.

The composite images shown in **Figure 3** provide examples of the use of near-peer presenters in heart- and brain-focused outreach sessions. The use of heart models and specimens (inset) is shown in **Figure 3A**. The use of human cadaveric brain specimens and models (inset) is shown in **Figure 3B**.

Figure 3 shows a 3D reconstruction of a CT scan in a patient with an occluded right coronary artery (**Figure 3C**, red arrow) and a coronary artery bypass graft (**Figure 3C**, black arrow). The use of wireless EEG recording of brain activity in an SP is shown in **Figure 3D**, including the raw EEG recordings (right panel) and the software visualization of the EEG activity in the brain (left panel). The recruitment of near-peer STEM role models is something that needs to be considered when broadcasting to middle and high school students. Near-peer high school presenters belonging to the STEM outreach team in this study were used to host virtual outreach sessions for children of staff working at a US federal agency during their sponsored "Take Your Child to Work Day" (a 30 min session on the heart²⁹ and a 60 min session on the brain³⁰).

The three-station integrated approach that was used in the described outreach presentations provides variety to the sessions and maintains student attention while using a web-based virtual video learning platform. More importantly, all three imaging modalities listed in the protocol require setting the stage for the students by reviewing some of the basic anatomy of the respective region (i.e., heart or brain). Virtual presentations can be easily tailored to the specific age and interest of the target audience. The protocol outlined in this paper has been used to provide virtual technology-focused STEM outreach presentations for a variety of middle and high

school audiences, as well as teachers, across the state. A sample listing of these sessions is provided in **Table 3**.

To evaluate the effectiveness of the virtual outreach presentations, teachers were asked for their perceptions of the value of the sessions. The nine teachers who responded represent classes that together totaled ~150 high school students. Teachers were emailed surveys and asked to evaluate eight statements about the virtual outreach sessions using a 5-point Likert scale (see **Table 4**). The data were collected and statistically analyzed. A one-sample *t*-test (two-tailed) was used to determine if the evaluation responses were significantly different than an expected neutral point of the scale (3, neither agree nor disagree) and to determine the significance (*p*-value) for each statement, including upper and lower 95% confidence intervals. The frequency of responses is included in **Table 4**.

The teacher evaluations indicated that these virtual sessions were a valuable use of class time ($p < .05$) and that students, in the opinion of the teachers, learned something about STEM or technology during the virtual sessions ($p < .01$). The teachers strongly agreed with the statement that they would recommend the virtual outreach sessions to other teachers ($p < .001$) and would invite the team to conduct another virtual outreach session ($p < .05$). Together, the data from these first six statements confirm that the approach seems to

be promising to provide a positive learning environment for students, despite being virtual. The final two questions asked about the level of engagement by those students attending the session either in person or virtually.

The neutral teacher evaluation data (i.e., no significantly higher or lower response compared to the neutral point) indicated that the students in their classes were not fully engaged by the virtual outreach sessions. The absence of a significant increase in this category of questions was not unexpected since hands-on activities engage students more than any virtual activity. The perceived value of the sessions by the teachers coupled with the absence of a significant negative evaluation for student engagement supports the use of these types of virtual outreach sessions when in-person, hands-on sessions are not possible.

Table 5 lists examples of the comments provided by students in the video platform chat bar on what they learned during the virtual sessions on the heart or brain. The presenter typically asks the class to provide examples of five things that they learned in the session that they did not know prior to logging into the virtual session. These comments indicated that students were paying attention during the outreach and that they were learning relevant content and confirmed the overall positive teacher evaluations.

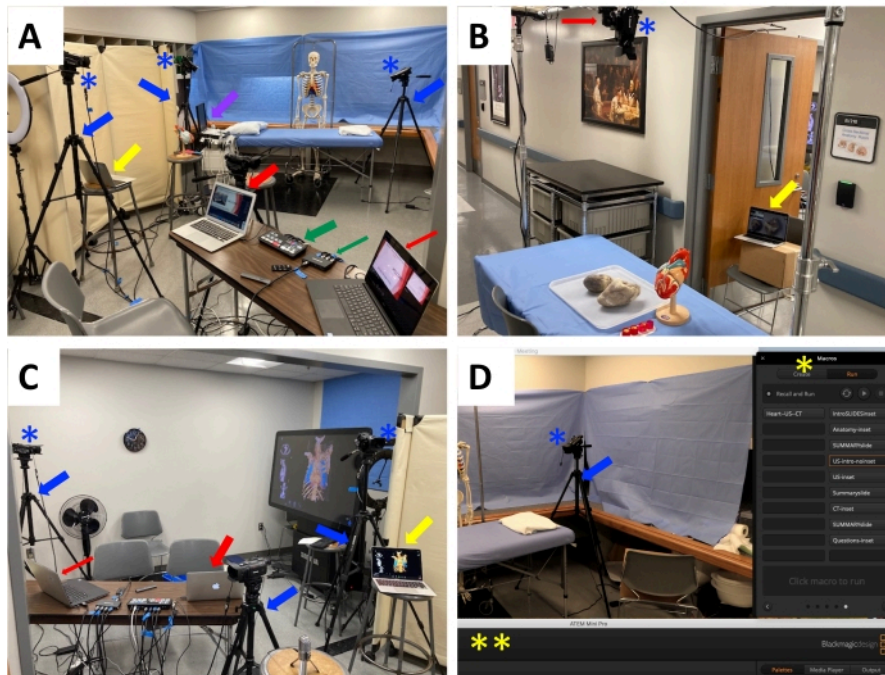


Figure 1: Makeshift broadcast studio with all the listed equipment. (A) View of the broadcast laptop (thick red arrow), slide presentation laptop (thin red arrow), video switcher (thick green arrow), HDMI multiport (thin green arrow), tripods (blue arrows) and mounted video cameras (blue asterisks), and ultrasound laptop (purple arrow). The camera near the broadcast laptop is aimed toward the hallway to capture the presenter at the anatomical specimen station. The tripod and camera on the left side of the photo provide the main camera view for the ultrasound station, while the cameras positioned at the head and foot of the massage table are used to provide close-up views of the SP during ultrasound scanning. The laptop denoted with the yellow arrow represents the broadcast monitor for the ultrasound station. (B) View of the anatomical specimen station with heart specimens and a heart model situated on the table and the overhead camera rig with its camera mount (red arrow) and video camera (blue asterisk) situated above the table. The laptop serving as the monitor for this station is denoted by the yellow arrow. (C) View of the CT imaging station with the vertically oriented anatomy visualization table (far-right side of image). The tripod (blue arrow) and video camera (blue asterisk) on the left of the image is the main camera view for the CT imaging station. The presenter at the anatomy visualization table station can simply watch the main broadcast laptop (thick red arrow) or the slide presentation laptop (thin red arrow) situated on the table. The laptop (yellow arrow) positioned on the stool on the right of the image is the monitor for the presenter at the ultrasound station. (D) Screenshot of the broadcast laptop during a live broadcast view of the ultrasound station with a tripod (blue arrow) and mounted video camera (blue asterisk) located at the foot of the massage table. The video switcher software control window (double yellow asterisks) is moved out of the way to the bottom of the screen. The macro popup window (single

yellow asterisk with the macro buttons positioned to the right of the screen). Abbreviations: SP = standardized patient; CT = computed tomography. [Please click here to view a larger version of this figure.](#)

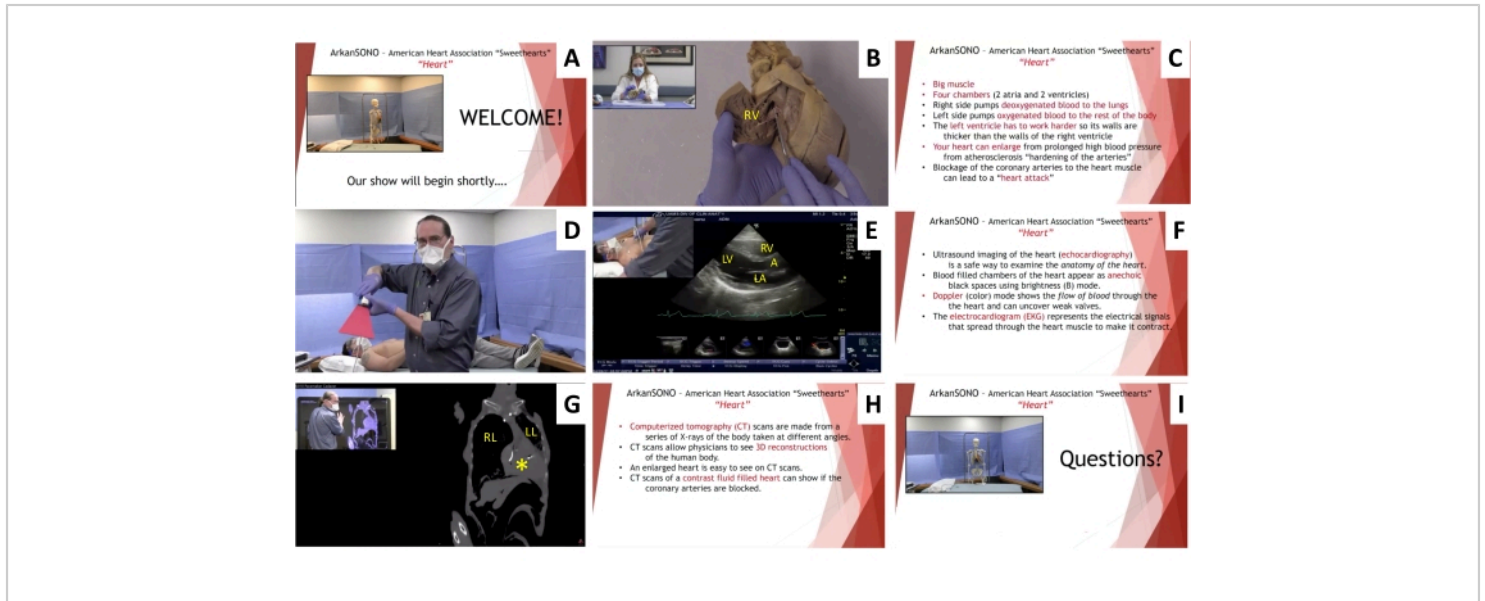


Figure 2: Sample video frames from a heart-focused virtual outreach session. (A) Example of introductory slides with live inset view from camera #1. (B) Anatomical specimen and model station with overhead camera view and live inset view from camera #2. The heart specimen has been opened to demonstrate the interior of the right ventricle. (C) Heart anatomy key point summary slide. (D) Ultrasound imaging station with live view from camera #3. (E) Ultrasound station with live inset view from camera #2 and ultrasound laptop video output. The scan is a parasternal long axis scan of the heart demonstrating the left atrium, left ventricle, right ventricle, and aorta. (F) Ultrasound imaging key point summary slide. (G) CT imaging station with live inset view from camera #4 and anatomy visualization table video output. The scan shows an enlarged heart (yellow asterisk) and the reduced size of the left lung compared to the right lung. (H) CT imaging key point summary slide. (I) Concluding questions from the audience slide with live inset view from camera #1. Abbreviation: CT = computed tomography; RV = right ventricle; LA = left atrium; LV = left ventricle; RV = right ventricle; A = aorta; LL = left lung; RL = right lung. [Please click here to view a larger version of this figure.](#)

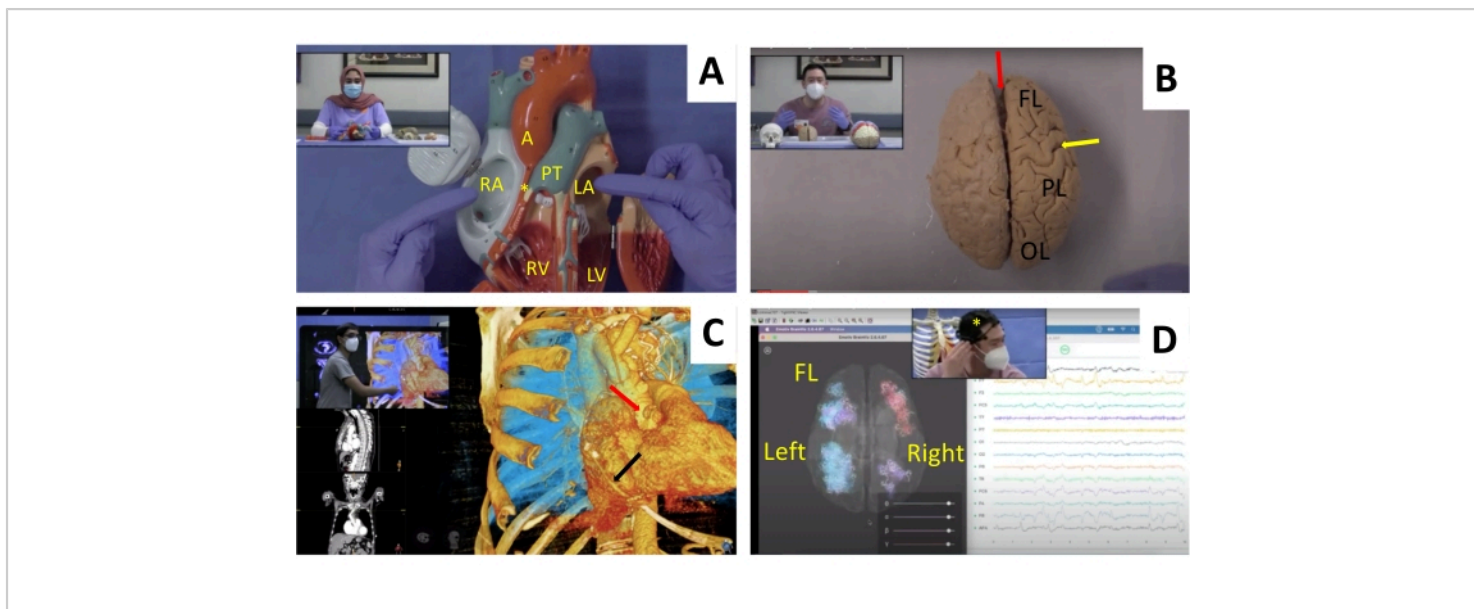


Figure 3: Using near-peer students in heart and brain presentations. Three near-peer students are shown as they present a virtual outreach session at the anatomy station (insets **A,B**) and anatomy visualization CT imaging station (inset **C**). One of these near-peer presenters served as the SP at the EEG station (inset **D**). Main images: **(A)** Heart model used to demonstrate the various parts of the heart, including the right atrium, pulmonary trunk, right ventricle, left atrium, left ventricle, and aorta. **(B)** Anatomical specimen station showing a whole human cadaveric preserved brain and the locations of the longitudinal fissure (red arrow), central sulcus (yellow arrow), frontal lobe, parietal lobe, and occipital lobe. **(C)** CT imaging using the anatomy visualization table showing an example of a heart scan with coronary artery bypass surgery with an occluded right coronary artery (red arrow) and the bypass graft vessel (black arrow). **(D)** Composite screen image showing EEG recording in an SP using a wireless EEG headset (yellow asterisk, inset panel), EEG recordings from the 14 leads of the headset (right panel), and brain visualization software reconstruction with a superior view of the brain localizing the EEG activity (left panel) in the left or right half of the brain. The frontal lobe is positioned at the top of the image. Abbreviations: CT = computed tomography; EEG = electroencephalogram; FL = frontal lobe; SP = standardized patient; RA = right atrium; PT = pulmonary trunk; RV = right ventricle; LA = left atrium; LV = left ventricle; A = aorta; FL = frontal lobe; PL = parietal lobe; OL = occipital lobe. [Please click here to view a larger version of this figure.](#)

Macro Soft Panel Button #	Saved Macro Button Name	Key Settings on ATEM Mini Pro
1	IntroSlides-inset	Cam 4; On Air; Cam 2 DVE; X position=-7.3; Y position = 0.3; X size = 0.49; Y size = 0.49
2	Anatomy-inset	Cam 1; On Air; Cam 2 DVE; X position = -10.2; Y position = 5; X size = 0.38; Y size = 0.38
3	Anat-SummarySlide	Cam 4
4	US-Intro-noinset	Cam 2
5	US-inset	Cam 3; On Air; Cam 2 DVE; X position = -10.2; Y position = 5; X size = 0.38; Y size = 0.38
6	US-SummarySlide	Cam 4
7	CT-inset	Cam 3; On Air; Cam 2 DVE; X position = -10.2; Y position = 5; X size = 0.38; Y size = 0.38
8	CT-SummarySlide	Cam 4
9	Questions-inset	Cam 4; On Air; Cam 2 DVE; X position = -7.3; Y position = 0.3; X size = 0.49; Y size = 0.49s

Table 1: Sample video switcher software control settings used for creating the heart video frames shown in Figure 2. The table lists the individual macro soft panel buttons, the corresponding button names, and the key settings on the virtual switcher software to enable various digital video effects. Abbreviations: CT = computed tomography; US = ultrasound; DVE = digital video effects.

Shot Sequence #	Soft Button Panel Selection	Additional Action to Prepare for Next Shot
1	Begin with IntroSlides-inset	[Presenter advances slides with remote]
2	Switch to Anatomy-inset	press camera 2 on remote and advance slides
3	Switch to Anat-SummarySlide	press camera 1 on remote
4	Switch to US-Intro-noinset	advance slides
5	Switch to US-inset	press camera 3 on remote
6	Switch to US-SummarySlide	press camera 4 on remote then replace US with SECTRA HDMI cable on ATEM
7	Switch to CT-inset	advance slides
8	Switch to CT-SummarySlide	press camera 1 on remote
9	Switch to Questions-inset and advance slides	

Table 2: Sample broadcast shot record for the heart presentation. The table lists the shot sequence, soft panel button selection, and additional actions required to prepare for the next shot in the virtual broadcast. Abbreviations: CT = computed tomography; US = ultrasound.

Group Description #	Student Grade	Virtual Outreach Topic	Stations
Middle school PreAP science class	8	Ultrasound and Infrared imaging	Measuring the speed of sound & infrared imaging
Summer Science STEM fair	6th - 8th	Skeletal demonstration	Anatomical specimen station
Weekly Anatomy and Technology Interactive - Summer Program 2020, 2021	6th through 12th	Heart	Heart anatomy, US of heart, CT imaging of heart
Weekly Anatomy and Technology Interactive - Summer Program 2020, 2021	6th through 12th	Lung	Lung anatomy, US of respiratory system, CT imaging of respiratory system
Weekly Anatomy and Technology Interactive - Summer Program 2020, 2021	6th through 12th	Brain/CNS	Brain and spinal cord anatomy, US nerves, CT imaging of skull and brain.
Weekly Anatomy and Technology Interactive - Summer Program 2020, 2021	6th through 12th	US of regions throughout the body	Ultrasound station
Weekly Anatomy and Technology Interactive - Summer Program 2020, 2021	6th through 12th	CT imaging of regions throughout the body	SECTRA station
High school science class	9th	Heart	Heart anatomy, US of heart, CT imaging of heart
High school science class	9th	Brain	Brain anatomy, CT/MRI imaging of skull and brain, EEG recording of live SP
Student Athlete STEM Academy (SASA)- Summer Program	9th - 12th	Muscle, tendons, joints, skeleton, heart, brain, skull	Model and skeleton demonstrations, US imaging of common sports injury sites, CT imaging of common MSK injuries, heart anatomy

Health Professions Recruitment and Exposure Program (HPREP)	9th - 12th	Heart	Heart anatomy, US of heart, CT imaging of heart
Rural school district high school science classes	9th-10th	Heart	Heart anatomy, US of heart, CT imaging of heart
Rural school district high school science classes	9th-10th	Brain and CNS	Brain anatomy, CT imaging of skull and brain
American Heart Association “Sweethearts” Program	10th	Heart	Heart anatomy, live US scanning of SP heart , EKG recording of heart pacemaker activity, CT imaging of heart
Cancer program – Summer (upper level high school and college)	11th and 12th and college	Review of cancer types, histology and pathology	Anatomy of major organs affected by cancer, US and CT imaging of these organs, virtual histopathology of cancer in these organs
Arkansas Science Festival	open to all interested grades	heart	anatomy, US, CT

Table 3: Virtual STEM outreach presentations and target audience. The table lists descriptions of representative student groups reached through outreach sessions, their grade levels, the main topic of the outreach, and the various stations included in the outreach. Abbreviations: CT = computed tomography; US = ultrasound; STEM = science, technology, engineering, and mathematics; CNS = central nervous system; EEG = electroencephalogram; MRI = magnetic resonance imaging; EKG = electrocardiogram. # Some student groups were recruited directly through known contacts, while others were recruited *via* website postings.

					One Sample t test (two-tailed)		
	Likert Response (Frequency)#	Average Evaluation	Standard Deviation	t	df	p-value	95% CI (lower, upper)
I believe this virtual classroom outreach visit was a valuable use of class time	1(0), 2(2), 3(0), 4(0), 5(7)	4.33	1.32	3.024	8	.017 *	3.316, 5.350
The topic was presented at an appropriate level for my students	1(0), 2(0), 3(0), 4(4), 5(5)	4.56	0.53	8.854	8	.000***	4.150, 4.961
I would recommend this outreach session to other teachers	1(0), 2(0), 3(2), 4(1), 5(6)	4.44	0.88	4.913	8	.001 **	3.767, 5.122
I would welcome the ArkanSONO team to conduct virtual outreach sessions next year in my classes	1(0), 2(2), 3(0), 4(0), 5(7)	4.33	1.32	3.024	8	.017 *	3.316, 5.350
I believe my students learned new STEM content in this session	1(0), 2(0), 3(2), 4(2), 5(5)	4.33	0.87	4.619	8	.002 **	3.668, 4.999
I believe my students learned something about technology in this session	1(0), 2(0), 3(2), 4(2), 5(5)	4.33	0.87	4.619	8	.002 **	3.668, 4.999
My in class students were engaged with this activity	1(0), 2(4), 3(0), 4(3), 5(2)	3.33	1.32	0.756	8	.471	2.316, 4.350
My online students were engaged with this activity	1(2), 2(2), 3(1), 4(2), 5(2)	3.00	1.58	0.000	8	1.00	1.784, 4.215
	# 5-point Likert scale					* p<.05	
						** p<.01	

							*** p<.001	
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Table 4: Teacher evaluation of the virtual outreach sessions. The table lists the teacher responses to eight different program evaluation questions using a 5-point Likert scale and the statistical analysis of the responses. Abbreviations: STEM = science, technology, engineering, and mathematics; df = degrees of freedom; CI = confidence interval.

Heart Session Comments	I learned about the different chambers of the heart, also about ventricles, also I learned how an ultrasound works.
	I learned how to identify the pericardial sack with ultrasound and possibly what to expect with bleeding
	I didn't know ultrasounds could be used on different parts of the body other than the abdominal cavity
	I learned that the sound of your heart beating is the valves opening and closing
	I didn't know how urine went through the bladder
	Ultrasound uses sound waves to see structures of the body, I thought it was like an x-ray.
	I learned what to look for and what things actually looked with an ultra-sound.
	I didn't know that you could see how all the muscles are moving on the ultrasound
	What bone looks like on an ultrasound and that an ultrasound uses sound waves.
	Before this zoom I did not know the purpose for the gel
	I knew that X-rays weren't safe, but I didn't know that ultrasounds are safe!
Brain Session Comments	I learned how different an Alzheimer patients brain looks than ours
	I did not know that stroke symptoms vary depending on what part of the brain is affected.
	I didn't know that you could put an EEG on your head and see the brain activity! That was super cool!
	I did not know that the frontal cortex did not fully develop until a person is in their late 20s
	I didn't know we could see the brains activity with a headset, I think it is really cool to think about Alzheimer's make the gyri shrink
	I didn't realize that babies skulls didn't fully fuse together until they grow up.
	I learned about the effects of aneurisms
	I learned the brain has two layers that protect it
	Your brain can look different and have a bunch of grooves from certain diseases brains and some functions they have
	I learned how the electrodes read the movement in the brain.
	I learned that CT is a 3D modal to see more details

	I learned that if you are right hand dominant then you use your left brain
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Table 5: Student comments-What did you learn today? The table provides representative student comments on what they learned in separately conducted brain and heart outreach sessions. The student comments were copied from the chat bar at the conclusion of the virtual outreach session.

Discussion

Federal grant-funded STEM outreach activities utilizing portable imaging technology resources available at the author's university were used to provide in-person, small-group, hands-on STEM sessions for middle through high school students. These efforts align with and bolster the already rich, university-sponsored K-12 STEM pipeline activities that are designed to increase the diversity of students entering STEM fields in Arkansas. The restrictions to campus access that arose in response to the COVID-19 pandemic forced everyone to reimagine hands-on STEM activities as virtual outreach events. Although small-group, hands-on interaction with technology should always be the goal for recruiting students into STEM fields, the use of virtual outreach sessions can help to broaden participation and bridge the divide in access to imaging technology. The research team in this study simply recruited students and teachers through online postings, existing community contacts, and through working with the University diversity affairs office.

Broadening participation is especially important in a rural state such as Arkansas. Medical schools are an important resource for modern imaging technology that can be used in virtual outreach settings to increase teacher and student knowledge of STEM concepts. The STEM outreach team in this project benefited from university investment of significant funds to obtain state-of-the-art ultrasound and CT imaging equipment (e.g., the anatomy visualization table)

dedicated for educational activities. A federally funded grant supplemented these technologies with the purchase of wireless EEG headsets and associated software packages that allow for imaging of the localization of EEG activity. Models and anatomical specimens were incorporated in each session since the anatomical sciences form the foundation for understanding the images obtained using modern imaging modalities such as ultrasound and CT imaging. The protocol outlined in this paper provides details on how a minimal investment in some key, additional, broadcast-related equipment will allow professional-looking livestreaming of these imaging technology resources in virtual, STEM-focused outreach events that will captivate and engage students.

The purchasing of high-quality video cameras, some switchers, and accessory items and the availability of other laptop computers allowed the team to provide high-quality video feeds for virtual outreach sessions. In the protocol described in this paper, six separate cameras were used in the outreach sessions (three for the ultrasound scanning, two for the anatomical specimen and model station, and one for the anatomy visualization CT imaging station). A high-quality transmission is important to maintain student interest, especially since the students will likely be watching the presentation on their classroom smart board or projector screen, both of which will likely result in a decrement in overall image quality. Lighting is important, but high-quality cameras may obviate the need for additional photographic lights.

The video switcher and multiple cameras are the most essential pieces of the system since they allow for the PIP capability. Replacing the built-in laptop computer video camera with the video switcher input provides the advantage that a larger portion of the screen is utilized for the livestreaming than would occur if the video presentation software was simply screen-shared in a live input from these technologies alongside the presenter camera. Studies have shown that live-composite video lectures where the lecturer's image is combined with slides or other content result in a better subjective experience for the students^{31,32}. A separate high-quality mobile microphone will enhance the auditory experience and will be required if the presenter is moving from station to station during the session at distances remote from the actual laptop being used to broadcast the virtual session.

A medical ultrasound laptop with HDMI output is required to provide a high-quality image for the virtual video platform broadcast. Commercially available 3D anatomy imaging tables such as the one used in the present protocol are a great resource that is available at many medical schools but are beyond the reach of most middle schools and high schools. The table used in this protocol has a virtual VH dissector program (not described in this paper) that allows for 3D and cross-sectional views of anatomy, which are useful in providing students with a reference point for understanding the anatomy that will be shown through ultrasound and CT imaging. The anatomy visualization table is connected to an Education Portal containing hundreds of cases of CT and MRI scans from real patients, which provides a perfect clinical focus for students. This allows the presenters to tie the CT imaging of the body organs with the US imaging and anatomical specimen demonstrations of the same organs. For example, using the CT views of the heart in different planes will help the students mentally construct a 3D image

of the heart and its relationship to other organs like the lungs. Providing students access to an annotated list of free, online CT imaging resources will provide them with a way to re-engage on their own with the technology after the session.

One of the more important resources of a medical school is its faculty and students, which can serve as professional STEM role models. The availability of the faculty for STEM outreach events is always an issue given the ongoing competing needs at a medical school campus. A cadre of the core faculty forms the basis of the STEM outreach team, but this team sometimes also includes near-peer presenters when possible (e.g., **Figure 3**). Although one person can potentially handle the entire virtual broadcast with intermittent interruptions to change the camera angles and video switcher settings, it is preferable to have one dedicated staff member to handle the video switcher and video platform broadcast program, which allows the presenter to focus on the virtual outreach content. The switching of roles is easy to accomplish behind the scenes when the summary slides are being broadcast to the participants. It is highly recommended that a third person monitor the chat bar if students are individually signing in to the outreach session. Having someone whose role is simply to monitor the chat bar and answer individual questions or interrupt the broadcast to ask anonymous questions is very helpful to engage quiet students. Middle and high school students, in particular, may not want to ask questions in large group settings, especially in what can be an impersonal virtual environment. A friendly message sent to all participants at the beginning of the session by the chat bar monitor establishes a safe place for students to ask questions. The chat bar monitor can even log on remotely to reduce congestion in the broadcast room.

One of the major challenges to successfully conducting a virtual outreach session is the lack of personal interactions and the ability to gauge student interest by seeing their faces. It takes time for the presenter to get used to not seeing the participants since the monitors are there to provide the presenter with the broadcast image and not the group of participant viewers. The presenter must rely upon the behind-the-scenes staff to monitor the session to get a feel for the level of student engagement and what might need to be changed for next time. Success in capturing the students' attention is evident when they lean forward in their chairs to seemingly get a better view. Intermittently asking for questions from the audience (e.g., just after the station summary slides) allows students time to process and reflect upon what they just learned. The student comments and teacher evaluation data provided in this paper support the conclusion that these types of virtual outreach sessions are effective in exposing students to new STEM and imaging technology content and provide students with a positive learning environment. These findings are in agreement with the results of other studies, which report that virtual outreach programs conducted during the pandemic can engage students just as much as in-person activities, allow for greater participation of students in STEM enrichment programs, and provide an avenue for building relationships between STEM professionals and students^{33,34,35}.

This paper has provided an outline of the equipment needed to use imaging resource technologies that may be available in a medical school setting to provide virtual technology-focused outreach activities to stimulate student interest in STEM fields. A small investment in equipment, such as a few high-quality 4K cameras, and other accessory items, such as the video broadcast switcher, can effectively increase the interactive feel of the presentations and lead to

visually pleasing virtual presentations that promote student engagement. Demonstrating live ultrasound scanning of a person, rotating 3D CT reconstructions of the body, and providing real-time EEG recording of brain activity help stimulate the STEM interests of middle and high school students. They also provide ways to counteract differences in access that rural students may have for resources at a regional medical school and for the loss of access by all students during the COVID-19 pandemic-associated restrictions.

Disclosures

The authors have no conflicts of interest to disclose.

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