THINK INSTRUMENTS, THINK APPS

Using App-Based Technology in the Science Classroom

by Nancy N. Heilbronner

Smart mobile devices such as cell phones and tablets are being integrated in classrooms as useful technology and have the potential to revolutionize education in the coming decades. Although most school districts banned these technologies when they were introduced, approximately 85% of school districts now have some type of bring-your-own-device (BYOD) policy, allowing students to bring their devices to use in class. Slightly more than half (52%) integrate mobile devices into the classroom experience (Godfrey 2013). Teachers can employ these devices in a plethora of instructional activities, bringing the power of learning through technology to individual students or to student groups. (While many schools have developed policies that protect students' privacy and safety during technology sessions, if your school has not done so, you will want to advocate for one; for examples of such policies, see Resources.)

The advent of mobile technology is especially helpful in science, as some of the new apps may begin to take the place of costly lab equipment, including scientific instruments. Previously many science teachers struggled to raise funds to purchase expensive items such as stopwatches, weather instruments, and more. But these instruments are now all available through apps that are either free or cost much less than their physical counterparts, and the technology through which they operate is continuously improving, making them a viable alternative in many cases.

The National Science Teachers Association recommends that teachers "implement approaches to teaching science that cause students to question and explore and to use those experiences to raise and answer questions about the natural world" (NSTA 2004). The first three crosscutting concepts in the *Next Generation Science Standards (NGSS)* call for students to be able to recognize patterns (concept 1), understand cause and effect (concept 2), and understand scale, proportion, and quantity (concept 3) (NGSS Lead States 2013). Core standards from the *NGSS* Engineering, Technology, and Applications of Science topic area also emphasize the development of problems and solutions (NGSS Lead States 2013). One way to enable our students to meet these standards and accomplish these tasks called for by the *NGSS* is to empower them to design their own scientific investigations. Embedding app-based technology is simply a way to heighten student interest and incorporate low-cost instruments as tools that enable students to design and carry out investigations.

Considerations

As with any technology, many factors influence how much can be accomplished with apps on smart devices. For example, limited school access to Wi-Fi might make it difficult to download apps in the classroom. In this case, apps can be downloaded at home, and many of them can be used at school without Wi-Fi access. Schools may opt to purchase sets of mobile devices with cellular technology to avoid Wi-Fi issues altogether, as well as the issues of students not having their own devices. It is important that teachers ensure all students can access at no cost the apps required for instruction.

Many students today own smart devices; in fact, more than two-thirds (78%) of all teens now own a cell phone. Almost half (47%) of these cell phones are

FIGURE 1 Ten instrument apps for use in the science classroom

App*	What it measures	Description	Extra features	Rating (out of 5 stars)	Cost	Device compatability
Free HD Compass	Directionality	A high-definition compass that provides directionality (directions and degrees)	The full version ($1.99) removes ads, provides a background map of where you are located, and allows you to change compass themes.	4 on Android, 4+ on Apple	Free	Android, Apple
Decibel Meter Pro	Sound levels (decibels)	Displays the average, peak, and maximum decibel levels from a range of 0 to 110 db; can plot a history of average values and export the data to e-mail	A display provides text-based descriptions for a typical decibel reading (e.g., "Avg. Home").	3 on Android, 4+ on Apple	$0.99 on Apple, free on Android	Android, Apple
Living Earth—Clock & Weather	Weather patterns	A live, high-resolution app that provides time and temperature readings for the entire globe; view a rotating planet (dark and light sides), cloud patterns, and weather trends for any location	Users can take a picture of any location and share it via e-mail, Facebook, or Twitter. The app also functions as an alarm.	4+	Free	Apple
Mission: Level	Determines when a surface is level	Allows users to determine when a surface is level or make it into a game by moving an indicator ball around four quadrants	Audible alerts and a lock mode	4+	$0.99	Apple
Leveler	Determines when a surface is level	Includes configurable background and one-button calibration	Makes a soothing sound when aligned	4+	Free	Android
Pro Metronome	Beats per measure or per minute	Allows you to set a time signature and hear any of seven metronome tones	An upgrade ($1.99) allows users to see a flash, as well.	4+	Free	Apple

FIGURE 1 Ten instrument apps for use in the science classroom (continued)

App*	What it measures	Description	Extra features	Rating (out of 5 stars)	Cost	Device compatability
Metronome Pro	Beats per measure or per minute	A powerful metronome that is easy to handle	You can change colors.	4+	$0.99	Android
Stopwatch & Timer	Elapsed time (counted up or down)	Functions as both a stopwatch and timer	There are no ads, and users can export times in an e-mail.	4+	$0.99 on Apple, free on Android	Android, Apple
Teslameter 11th	Magnetic pull	Uses the built-in magnetometer to monitor the strength of a magnetic field	Users can record and export data to e-mail for further analysis.	4+	Free	Apple
Thermal Camera**	Heat indicators	View and save pictures of heat levels as different colors	An upgrade ($0.99) will allow you to receive an ad-free version.	4+	Free	Android, Apple
Thermo	Weather indicators	Displays the present temperature in Celsius or Fahrenheit in a thermometer graphic for any location in the world; provides yesterday's temperature and what today's temperature "feels" like	An upgrade ($1.99) allows users to track in a line chart personal temperature records.	4+	Free	Apple
WeatherBug	Weather indicators	Pinpoints weather indicators for 2.6 million locations worldwide	Lightning detector	4+	Free	Android
Vital Signs Camera: Philips	Heart rate and breathing rate	Uses camera technology to measure users' heart rate from the changes of color in their face; tracks movement in the chest to measure breathing rate	The app graphs heart or breathing rate, and users can compare heart or breathing rate to a daily or hourly average.	4+	0.99	Apple

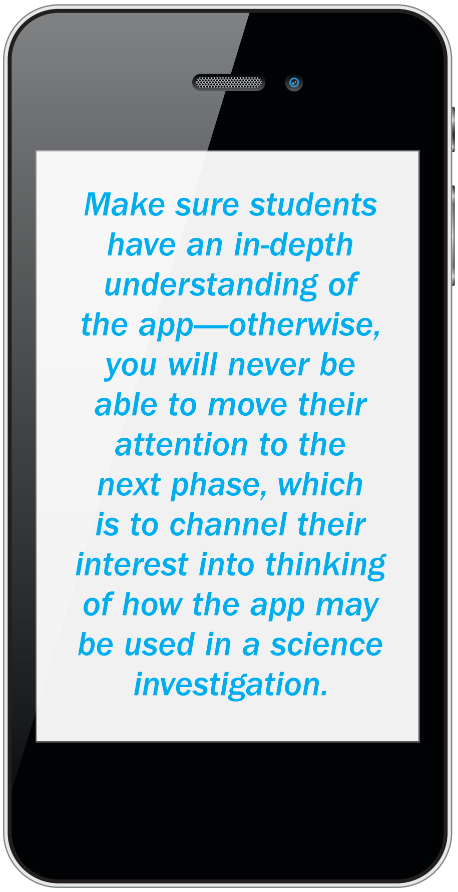
*Apps change frequently in the Apple and Android stores; if the app listed is not available, a similar app may usually be found by using appropriate search terms (e.g., "stopwatch").

**The Thermal Camera app provides a lighting effect via a filter and does not itself measure radiant heat energy, and so some degree of inaccuracy may occur.

smartphones, and that percentage is increasing rapidly (Pew Research Center 2013). For students who do not own a smart device, several options exist. First, you might try structuring the lesson so that students share devices, although this may prove problematic in some cases. A better option could be to procure additional technology, possibly through grants; K–12 education grants provide hundreds of millions of dollars for this purpose (see Resources).

Apps to replace science instruments

Currently Apple and Android each offer over one million apps for their mobile devices (148Apps.biz 2014; AppBrain 2014). It was inevitable that a number of high-quality apps would emerge that could take the place of scientific instruments in the classroom. Figure 1 describes 10 apps that students can download onto their smartphones or tablets for use in the science classroom. Although there are many more apps available, these 10 were selected because (a) they are high-quality apps that have received excellent reviews from the Apple App or Android store (4 out of 5 stars as rated in the Apple or Android store by customers); (b) they are low cost ($2 or less); and (c) they allow teachers to replace physical scientific instruments in their classrooms. (See also *www.nsta.org/recommends* for app reviews.)



Using the apps

After your students have downloaded one or more of these apps onto their smart devices, how might you use them in the science classroom? One way is to simply substitute them for traditional instruments. For example, the stopwatch/timer app might be used in classroom investigations in place of a traditional timer, or the thermometer app might be used to chart outside temperature. However, these apps could also be used to interest students in designing their own science investigations. An example of a lesson using instrument apps is provided below.

Prior to the investigation

Begin by asking students to download the app they will be using. Students might purchase their apps using a fund set up by the school, the district, or the PTA. Once they have downloaded it, allow students time to explore and become familiar with the app. I call this "taking it out for a test drive," because students want to click on all of the links and explore all of the features. Make sure students have an in-depth understanding of the app—otherwise, you will never be able to move their attention to the next phase, which is to channel their interest into thinking of how the app may be used in a science investigation.

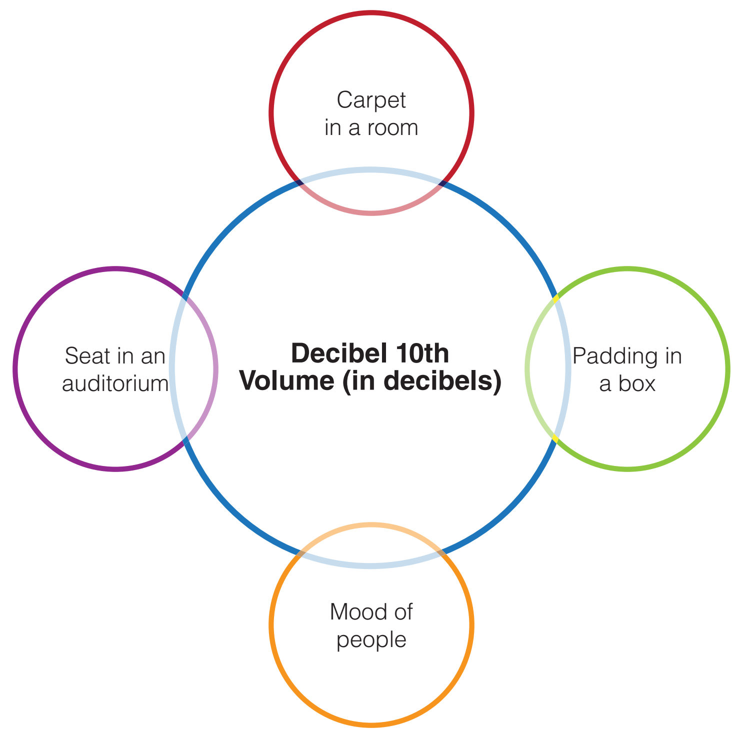
After students have downloaded and explored a particular app, ask them what it measures. The answer to this question actually has two parts: what the app measures and the unit of measurement. For example, if your students download the Decibel Meter Pro app, they should be able to tell you that it measures sound levels (what it measures) in decibels (unit of measurement). Once this concept is clear in their minds, students can begin to think of science investigations that they can do with the app.

Developing an investigation

You may wish to have students work in small groups (three to five students) for this part, although it is certainly possible for each student to complete an individual investigation. Each student can have a device if there are enough available, or groups can have one instrument investigator who controls the smart device. Figure 2 shows a graphic organizer students can use to develop an investigation. At the center of the figure, write the name of the app and the two parts of what it measures. Again, the first part should be what the app measures (e.g., volume) and the second part should be the unit of measurement (e.g., decibels). Tell students that they can design investigations using the thing that the app measures as the dependent variable. Then ask students to think of factors that could affect what is being measured and record these factors in the outside circles. Figure 2 has been completed for use with the Decibel Meter Pro app.

Some of these factors may seem obvious to students, while others may be arrived at through classroom discussion. For example, students may readily understand how the amount of padding in a box or the type of carpeting in a room could affect sound levels inside a box, but they might struggle more with how people's moods or seating in an auditorium may affect sound levels. You might ask your class, "Have you been in any situations where you've noticed sound levels have gone up and down?" Someone might suggest that they have attended concerts in the school auditorium and noticed that the sound is different when they sit in different seats. They might be led to propose that distance from the stage, or even the angle between the source of the music and the listener, might have an impact on volume. Another student might mention that at times the noise in the cafeteria seems louder or softer, even though the same numbers of students are present. Through classroom discussion, you could guide your class to the realization that students might be excited on some days for a number of reasons, such as an upcoming holiday or anxiety about a state test.

FIGURE 2 Graphic organizer for planning investigations



Once students have completed the outside circles in the graphic, tell them that these factors will lead them to identify the independent variable for their investigations. Help them to understand that an independent variable is one that varies (changes) in an investigation while other things stay the same. Again, the dependent variable (sound levels) is what is being measured; it is recorded in the center circle of Figure 2. Let them know that it is important to focus on one independent variable at a time.

Discuss each factor with students and use Figure 3 to help them determine whether they could develop a research question and investigation for that factor. Using the factors identified in Figure 2, ask each group to select one independent variable to investigate and develop a research question. Show them a set of research questions, which might include the examples in Figure 3. Here you will wish to focus on *NGSS* connections in both your lesson planning and with students. For example, if you're discussing sound, you might wish to focus on disciplinary core idea PS4.A: Wave Properties from standard MS-PS4 (NGSS Lead States 2013), and discuss related content with students. What might be going on? Why might sounds behave in the manner in which students have observed? Indeed, this type of discussion may lead students toward the recognition of patterns (crosscutting concept 1). The investigation itself will refine students' abilities to recognize cause and effect (crosscutting concept 2) and measurement (crosscutting concept 3).

FIGURE 3 Examples of research questions

Factor 1	
Independent variable	**Research question**
Type of carpet in a room	*Does the type of carpet in a room affect sound levels?*
Factor 2	
Independent variable	**Research question**
Thickness of padding in a box	*Does the thickness of the padding in a box affect outside room noise levels recorded in the box?*
Factor 3	
Independent variable	**Research question**
Mood of people (happy, sad, angry)	*How do people's moods affect noise levels in a room?*
Factor 4	
Independent variable	**Research question**
Seat in an auditorium	*Do noise levels vary by one's seat in an auditorium?*

Once each group of students has developed a research question that focuses on one independent variable, the groups will be able to use instrument apps to carry out their initial investigations. You will want to have them work together to gather data and draw conclusions. Be sure to allow some time for reflection, as well.

Example investigation

What might a typical investigation look like, from start to finish? Let's take the example of how students might use the decibel app, Decibel Meter Pro, to conduct their own investigations. If students are investigating whether the thickness of an insulating material changes decibel readings, they might line a cardboard box with an insulating material. They could use a second smart device to generate a constant sound (e.g., a bell—these apps are available). Students then place the device with the decibel meter inside the box and record the level of the sound in a data chart.

After several repetitions, students average the decibel levels and record this average on their data chart; keeping the type of insulation constant, students increase its thickness, thus adjusting the independent variable of their investigation. Students run the same number of trials as before, this time recording the decibel levels when using the thicker insulation. They average and record as before. Students repeat this process, each time increasing the thickness and then comparing the average (mean) decibel readings at each level of thickness. If students have completed the process correctly, they should find that increasing the thickness of the insulating material decreases the decibel levels. If all groups are investigating the same question, they compare results and look for patterns in the data so that they can draw conclusions. Students reflect on what happened and discuss it with you, the teacher, and the class. In this way, learning is inductive and inquiry-based.

Reflection and assessment

You will want to encourage students to reflect on their investigation, for it is in the reflection that much learning occurs. Inquiry is not linear, and we can't break learning down into neat conclusions. If students end up with an "incorrect" answer to their investigations, encourage them to think about what they did and how it might have affected their outcomes. If something went wrong, was there some extraneous variable that might have caused the results? The identification of extraneous variables is made easier if the investigation is repeated or if more than one group is conducting the same investigation. For example, if three groups of students conduct an investigation on whether carpet absorbs sound, and if two of the groups get the same results and one does not, a discussion might occur among members of these groups about how each group conducted its investigation. It may come up that the group with the different result did something slightly different (e.g., the group might have been working in a room that was noisier to begin with or larger), and this might account for the different result.

Sometimes these investigations will lead to larger and perhaps more authentic investigations. Authentic investigations have several characteristics: They present a problem that is real, students care about the problem, and the problem should target an authentic audience beyond the teacher and the classroom (Renzulli, Gentry, and Reis 2004). For example, suppose that students become concerned about the impact of noise levels on their school, a not unreasonable assumption if the school is located near a highway or construction site. They could come up with the idea of using the Decibel Meter Pro app to document noise levels at different times of the day in different areas of the school and present a summary of their investigation to the school board. Based on students' findings, the school board might decide to support a tax referendum to raise money to soundproof portions of the school.

Conclusion

Science education is at the edge of an exciting new time—technology is evolving quickly, and educators must evolve with it. Twenty-two percent of children ages 6 to 9 now own cell phones, and 60% and 84% of children ages 10 to 14 and 15 to 18, respectively, own them. We have come a long way since 1995 and the advent of internet in schools—let's use portable devices in the classroom to inspire and engage students. ■

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Resources

BYOD policy examples—*http://byod.wiki.caiu.org/Policy+Examples*

K–12 education grants—*http://technology-grants.com/page/k-12-education*

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