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# Soundscapes

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## Abstract
Today computer music is the dominant form of reproduced music and computers are widely available in the home and in science laboratories. The advent of new technology prompts us to rethink not only how we teach, but also what we teach. In this article I present a possible new approach to the teaching of sound based around these new technologies

(Some figures in this article are in colour only in the electronic version).


## Opening thoughts

About 20 years ago the technological hook for getting into the study of sound, often via music, was the tape recorder. The purpose of this article is to suggest that the time may have come to shift the computer to centre stage. I think there are three reasons why this is so.

- Plenty of music is in any case computed these days (MP3, mini-disc, CD, DVD), rather than relying on analogue production (audio cassettes, LPs, most wireless, television)[1].
- A headcount on my bus suggests that amongst the young the vast majority of music reproducing devices are in fact digital: the music is literally reconstructed from a string of numbers. This forms an exploitable bridge from their world to physics.
- You hear as a range of frequencies arriving instant after instant, not as a waveform spread out over time, so it may be easier to build up an intuitive understanding of sound starting from seeing sound in this way: the computer allows you to do this.

The essential key is that computers enable pupils to look not only at a waveform view, but perhaps at a spectral view—they allow us to see things in ways that were not possible. Previously we would rely only on an oscilloscope to give us the view of the sound. I think this new view, concentrating on frequencies rather than on waveforms, has much to commend it.

The spectral approach works particularly well if we have fresh look at curricular requirements for 11–14 year-olds, taking the English national curriculum requirements for Key Stage 3 as a typical example. At KS3 we are asked to introduce children to the ideas of amplitude, frequency and hearing ranges, whilst relating these scientific descriptions to what they hear.

One advantage of starting by analysing frequency is that we might allay difficulties about distance and time axes on wave-like displays (a perennial confusion, I find—reading axes is such hard work!). Frequency, after all, is just to do with counting. Frequency is about counting in time rather than over distance, so laying the things to be counted out in a line might not help beginners, particularly since the axes measure wavelength directly (useful later), but the inverse of frequency directly (not so useful for now). Ever since the earliest dataloggers (such as the 'Vela') we have had cheap digital frequency meters in the lab, so why not exploit them, making starting out in sound easier?

Following these thoughts, here is a sequence for getting into sound. I expect this will need adaptation and modification in order to fit your pattern of lessons and your pupils, but I hope that some of this might be worth trying out. I

[1] This may have implications for the teaching of electromagnetic induction—but that is for another time.

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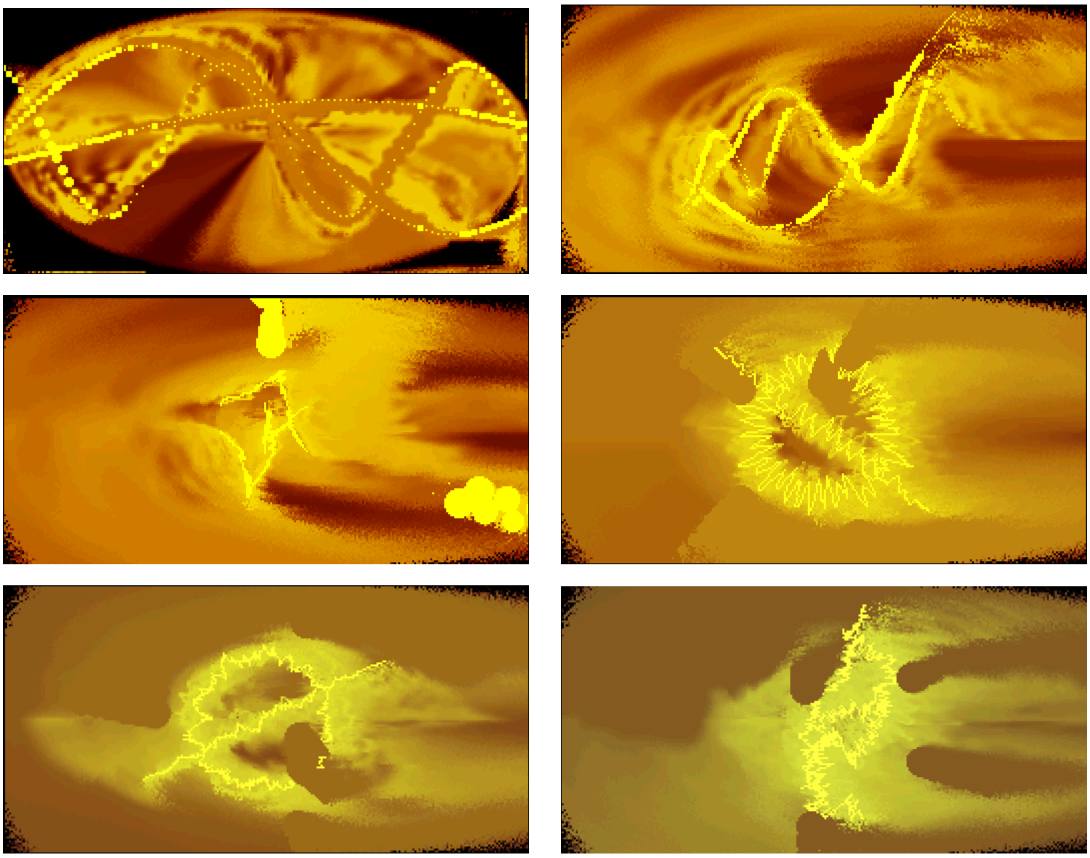

**Figure 1.** A sequence using iTunes.

certainly expect it to provide some powerful events for stimulating interest and providing a focus at the start of lessons.

In what follows I have assumed a Macintosh computer and a selection of freeware and shareware. I fully expect most of this to be available on other platforms, and am reasonably confident that you will find substitutes at least on Windows. So you can get started without a great financial outlay.

## Graphics and music

*Step 1*

I'd start with iTunes, an MP3 and CD package included with the Mac OS, with some music playing. This could serve as a light introduction to computation and music, with the sub-theme that music can be seen as a stream of data that can be manipulated. The first look at this is very unthreatening, but rather beautiful, as the program uses the patterns in the music as a basis on which to modify the graphics. One sequence is shown in figure 1.

Looking for patterns in these displays, correlating these with what you hear, is, I think, likely to lead to pitch and loudness being identified as significant determinants—or at least one of them, which is all the excuse I'd need to move on to the next step (again with iTunes to avoid too much hopping between applications).

*Step 2*

This next step is to look at, and listen to, a selection of pieces of music with a graphic equalizer (figure 2).

I'd use this tool at this introductory stage, in preference to a more analytical tool, as I'd expect it to have resonances in the world of the student, making connections to artifacts and experiences common to them. Almost any tune can do for

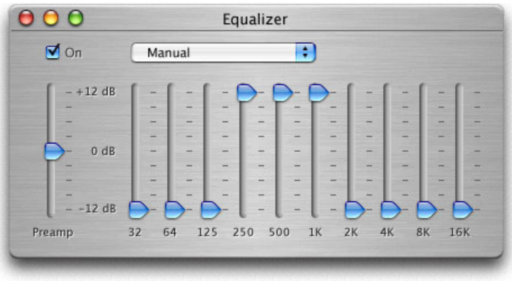


**Figure 2.** A graphic equalizer.

discussion of changes to the volume, controlled using the left-hand slider.

Well selected pieces, with a wide range of frequencies present, will sound very different when played back with different ranges of frequencies enhanced or suppressed via the remaining sliders, so serving to open up discussion of frequency. This is a good time to start to introduce the fundamental role of frequency in providing an account of music and sound, perhaps even a time to begin to introduce the quantification of frequency. It will also provide a good tool for empathizing with the hearing-impaired, due to the ability to suppress a range of frequencies, then hear the result.

The advantage of having both a repeatable short digital extract and the processing tools to hand is that many suggestions from the class can be tried out there and then, with the results being heard by all. (A practical hint here: most laptop speakers do not carry well over a class, but the small powered speakers to supplement the headphone socket of personal music devices, or provided with multimedia PCs, are fine.)

I am sure that alongside using these kinds of tools for emphasizing the centrality of loudness and frequency, you'll want to include some simple demonstrations of oscillating things providing a range of pitches and amplitudes. (In fact this might provide an interesting basis for some genuine investigative activity.)

## An interlude for pleasure and recap

The centrality of frequency can be revisited in using another piece of technology to control the playback of digitally encoded music. 'Amazing Slow Downer' (figure 3) allows you to independently alter the pitch and playback rate of any MP3 or CD track on the fly. Try it, predict what you

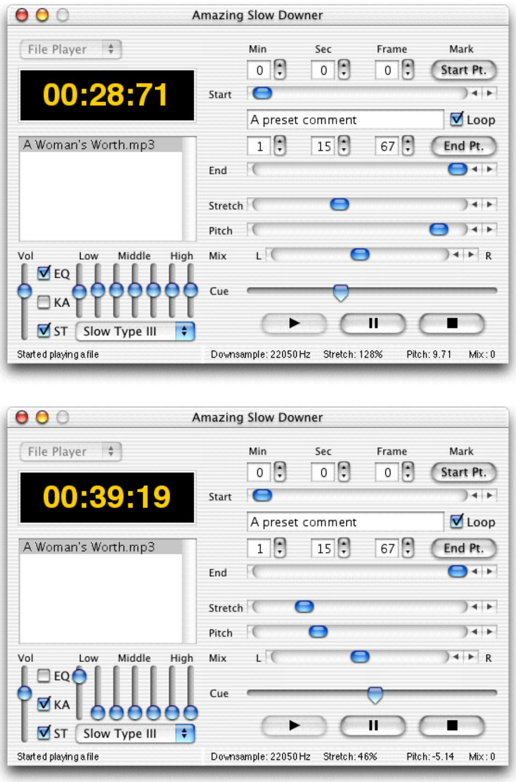


**Figure 3.** The 'Amazing Slow Downer'.

will hear; discuss what you do hear. Share the smile with your classes. Alicia Keys (substitute as appropriate for local taste) heard note by note at Basso profundo and then at a similar rate Falsetto is an experience likely to be talked about beyond the confines of the lesson!

It is the settings on the Stretch and Pitch sliders that I'd vary here.

## A more analytic approach

I'd be tempted to move to from listening and manipulating to listening and analysing, with a particular emphasis on using a number of representations to depict the sounds. For this I would choose the package Amadeus. Here the link between the representation and what is heard needs a fully interactive explanation, so if I could not whistle well, then I'd invest in a cheap electronic keyboard, to allow a range of notes and chords to be generated.

Such packages offer a plethora of views, but it may be as well to start with the more direct, simpler ones. These will be characterized by providing

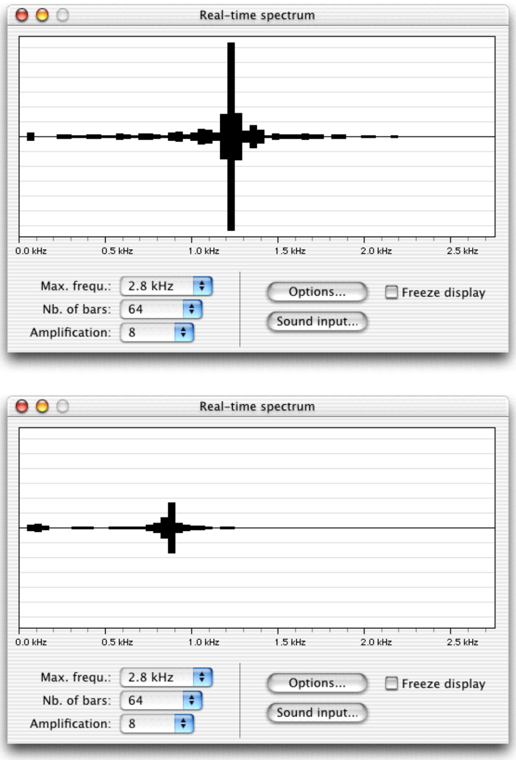


**Figure 4.** A pair of whistles.

exactly what you want as stepping stones towards a full understanding. Displays of amplitude and frequency responding in real time to inputs via a microphone will be highly desirable. In this way you can correlate what you hear with what you see.

Figure 4 shows a pair of whistles, showing the differences in pitch and loudness as frequencies and amplitudes. (The use of the term amplitude is somewhat loose here—I return to that point later.)

This can be extended to see who can produce different notes, what the frequencies produced by different instruments are, and other explorations. Other instruments produce interesting patterns, such as those in figure 5 produced by a piano, in some cases playing chords. One worth a comment is the bottom one in figure 5, frozen towards the end of a sustained single note.

Having powerful analysis tools to hand makes it possible to explore and then make sense of these kinds of findings—but you will want to practise a little to select the range of 'findings' appropriate to your purposes for the class.

Moving on a couple of steps, I'd show both a range of frequencies and how loud the sounds are, introducing a quantification of the vertical axis. In figure 6 we have the background noise, then a whistle overlaid.

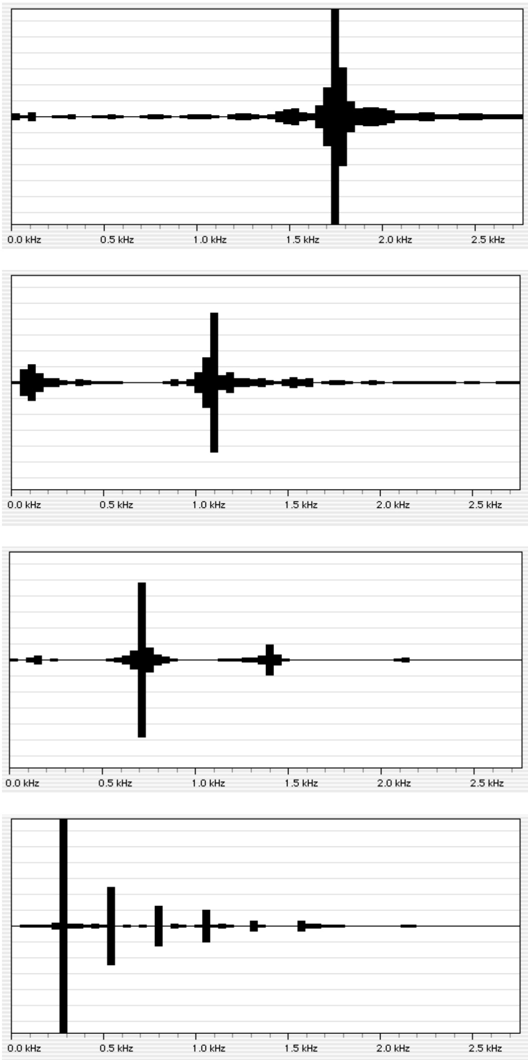


**Figure 5.** Patterns produced by a piano.

This is simple, but the range of sounds to be analysed need not be so: this might be the time to return to a piece of music, seeing how the blend of frequencies changes over time.

A final step, which may be more appropriately delayed for pupils, apart from those showing real interest and aptitude, is to record the sounds and then to analyse these captured data using waveform and spectral views. Here you have delayed gratification, but access to greatly improved analytical and manipulative tools. You can see the frequencies contributing over time,

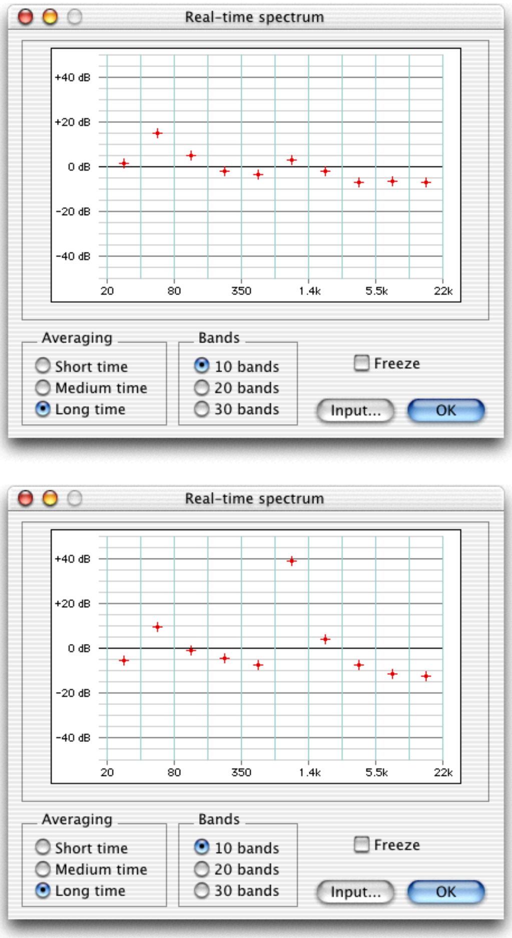


**Figure 6.** Background noise, then a whistle overlaid.

colour coded to relative intensities, and here clicking to reveal a particular value (figure 7). I think this is far more informative than the waveform view for the core purposes in teaching 11–14 year-olds.

Further work can involve filtering the sound, to remove particular frequencies, or adding together component frequencies to produce a complex sound. In all cases the power of the system comes from being able to hear the sounds and see the representations, so allowing connections to be made. Further intelligibility is added through the ability to manipulate the data, and then to re-present the data, both as a reconstructed phenomenon and as a cunningly chosen series of representations. This kind of activity is explained and supported fully in the Advancing Physics course.

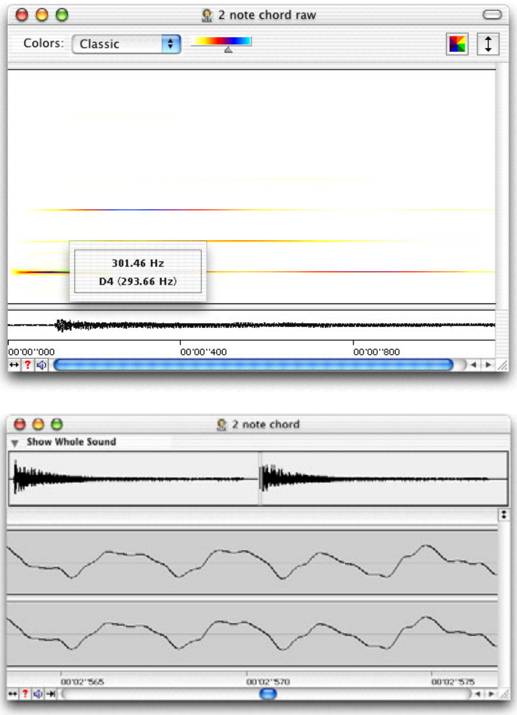


**Figure 7.** Spectral and waveform views.

Here, matching the learning to the learners, we are going for limited manipulation and a semi-quantitative understanding. At KS3 we want pupils to understand that higher pitches are correlated with higher frequencies, but they do not need to know the significance of 440 Hz, or the increase in frequency when moving from middle C to an octave above. They should also be learning about the decibel scale but they don't need to know the details of the scale's construction. The displays I have chosen make these features available, but do not depend on them for their fruitfulness!

## Closing thoughts

More established analogue technology still has its place: simple artifacts that make noises and allow simple direct physical experiences should not be spurned. But the case I seek to simply make here is that we can choose the displays we use to represent sounds. We should take time to make these choices carefully: they have significant impact on the learners. Further I contend that we should be looking to information and communication technology to give us these kinds of choices in the sciences.

I am fairly certain that I would no longer want to use an oscilloscope in teaching sound, where the fundamentals are frequency and amplitude. Perhaps the tools now available also point to the need to update curriculum requirements. I am not so sure that amplitude should be seen as a starting point any more—although I guess we could introduce it as being proportional to the square root of the loudness . . . just joking!

Once you have played with these tools for a while, you'll realize that the sequence here is far from immutable. On another occasion, with a different class, I might well have started with the MTA display from Amadeus, playing different pieces of music to see how the loudness and pitch match up to the amplitudes and frequencies, then introduced the more common replay packages.

## Finding out more

All the tools mentioned here can be found from www.apple.com/downloads/macosx/audio, where a list of links is provided. If I were to try to find a set of tools at low cost to do a similar job for Windows I would begin at www.tucows.com. More on Advancing Physics can be found at advancingphysics.iop.org.

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