



Building a seismograph from scrap

Did you know that you can use old hi-fi speakers to detect earthquakes? And also carry out some simple earthquake experiments in the classroom? Here's how.

Earthquakes occur around the world all the time. In 2011, the earthquakes that caused the Fukushima disaster in Japan killed thousands in Turkey and devastated New Zealand's second-largest city made the headlines. But did you know that 2011 also saw earthquakes in Finland, Belgium, and the Czech Republic?

Some earthquakes may be so slight as to be practically unnoticeable, but they can still be recorded. Each tremor produces different types of vibration, or seismic waves, which travel through Earth's interior with different velocities. These waves can be detected and recorded by instruments called seismographs, which are often sited at great distances from the earthquake. By measuring the time that the seismic waves take to arrive at seismographs, as well as recording the amplitude and duration of the waves, we can calculate the magnitude of the earthquake and determine its epicentre.

Monitoring local earthquakes

Earthquakes are a daily occurrence in Greece, sitting as it does at the boundary of two tectonic plates. The district of Messinia, where our school is located, has a history of major earthquakes. In 1886, [a severe earthquake of magnitude 7.5 on the Richter scale struck Filiatra](#). A century later, [Kalamata was hit by another strong earthquake](#), this time of magnitude 6.0. Within the next 100 years, it is predicted that [Sparta will be struck by an earthquake](#) of at least magnitude 7.0.

To encourage my students to learn about earthquakes, I acquired and set up a commercial, educational seismograph in our school (Figs. 1 and 2a), the General Lyceum of Filiatra. The seismograph is based on an array of three geophones – devices that respond to the seismic waves and convert them to electrical signals. Each of the three geophones monitors waves in the up-down, east-west or north-south directions. The three signals are then processed by computer, allowing the magnitude of the earthquake and the distance from the epicentre to be calculated (Fig. 1).

Building a seismograph

I also wanted to encourage the students to think about the technology that is used to detect and measure earthquakes and to understand what each component does, rather than viewing a seismograph as a 'black box'. To this end, we build our own seismograph, with which we can detect local earthquakes – up to 100–200 km away, depending on their magnitude.

At the heart of any seismograph are the geophones. They convert the ground vibrations into electrical signals using a coil that moves

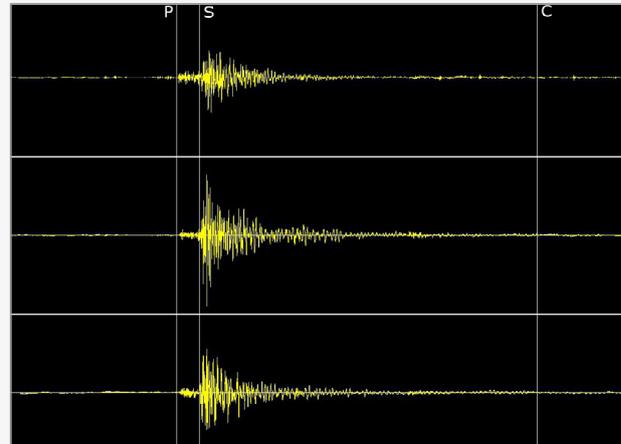


Fig. 1: A 3-channel seismogram from our commercial seismograph, showing the start times of the primary (P) and secondary (S) waves and the vibration end time (C). **Primary waves are compressional longitudinal waves** that are the first to arrive at the seismograph. They can travel through solids or fluids – in air they take the form of sound waves, travelling therefore at the speed of sound (340 m/s). In water they travel at about 1450 m/s and in granite at about 5000 m/s. Secondary waves are shear transverse waves, arriving at the seismograph after the primary waves and displacing the ground in a direction perpendicular to the direction of propagation. They do not travel through liquids or gases, travelling through solids at speeds of about 60% of those of primary waves. The epicentre distance (in km) and the earthquake magnitude (measured on the Richter scale) are calculated according to the formulae

$$\text{distance} = p_1 \cdot (t_s - t_p), \text{ and } \text{magnitude} = p_2 \cdot \log_{10}(t_c - t_p) + p_3 \cdot \text{distance} - p_4,$$

where p_1, p_2, p_3, p_4 are constants that depend on the types of rock that the earthquake passed through. Default values are $p_1 = 7.6, p_2 = 2.31, p_3 = 0.0012, p_4 = 1.0$. Three time measurements (in seconds) are needed: the time that P waves arrive (t_p), the time that S waves arrive (t_s) and the time that vibrations end (t_c). (Credit: Panteleimon Bazanos; image source: Seismic Logger, Helicorder and Dataviewer software, Seismology Laboratory of the University of Patras)

relative to a magnet, producing an electrical voltage at the end of the coil (Faraday's law; Fig. 2a). To build our seismograph, we used everyday technology as the geophone: a loudspeaker. Normally, loudspeakers operate by converting an electrical signal into the relative movement of a coil and a magnet, which causes the cone to move in and out, thus generating vibrations: sound waves (Fig. 2b). By making them operate the other way round – turning vibrations into electrical signals – they can be made to function as geophones.

To make our geophone, we used a 'woofer' – a speaker for low-pitched sounds – because woofers are designed to work well for low frequencies, and seismic waves are of course low-frequency vibrations. To minimize interference from sound vibrations, we removed the cone of the loudspeaker.

To complete our geophone (Fig. 3), we also used a weight, a spring and the lid of a spray can. The weight serves to increase the inertia, as the loudspeaker coil itself is very light. Placing a weight directly onto the coil would damage it, so we used the spring to hold the weight over the coil, allowing it to oscillate. The lid protected the coil. We then plugged our woofer geophone into the sound-card port of a computer, and recorded the signals using sound-editing

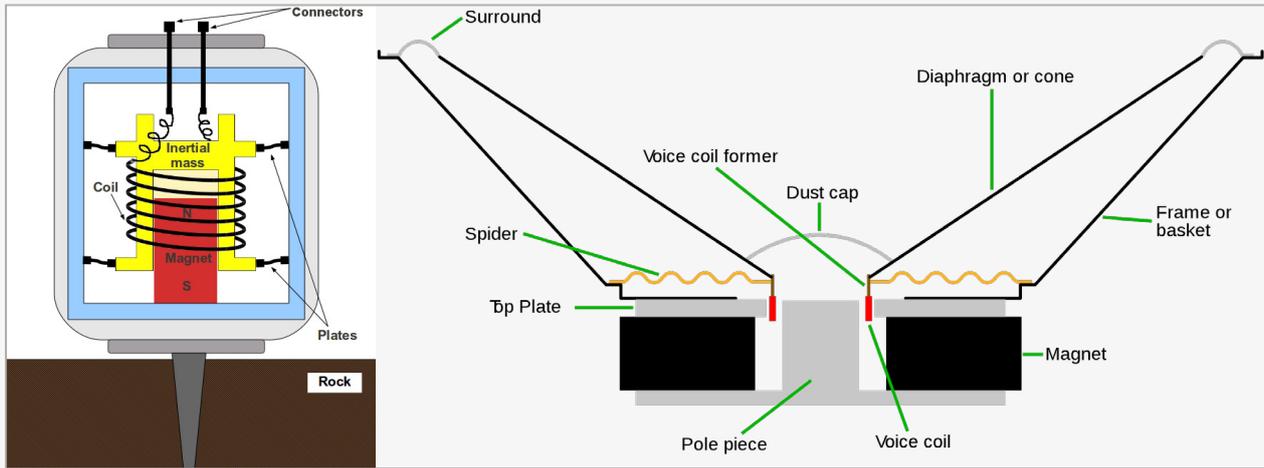


Fig. 2: a (left): How a geophone works. When the ground vibrates, the mass with the coil attached to it moves relative to the magnet. The potential difference produced in the connectors depends on the way the ground vibrates. (Credit: Panteleimon Bazanos)

b (right): How a loudspeaker works. As the function of loudspeakers is based on the relative movement of coil and magnet, we can use them to detect ground vibrations. These vibrations move the coil relative to the magnet, producing a potential difference between the coil's connectors. This electrical signal is recorded by the computer via the sound card, in the same way as [input from a microphone would be](#). (Credit: Iain Fergusson; image source: [Wikimedia Commons](#))

software, creating a working seismograph. Detailed instructions for building our seismograph can be [downloaded from the Science in School website](#).

Now it's your turn

If you are interested in monitoring and investigating seismic activity in the classroom, you could:

1. Monitor and analyze [data from existing seismographic stations](#).
2. Use a commercial, educational seismograph.
3. Construct your own seismograph, using the [downloadable instructions](#).
4. Carry out some simple experiments (detailed below) to simulate and investigate the physics of earthquakes.

To record earthquakes with either a commercial or a homemade seismograph, you will need to be relatively close to their epicentres. [Our homemade seismograph detected earthquakes up to 100–200 km away](#), depending on magnitude. With our [commercial seismograph](#), we detected earthquakes of 4.0 on the Richter scale from 500 km away.

Options 1 and 4 have the advantage of being feasible even in regions with very little seismic activity.

Looking for earthquakes

The coil of the homemade seismograph is very sensitive, so the geophone must be handled with great care. For the best measurements, set up the seismograph somewhere quiet and free from vibrations, perhaps in the school cellar. However, to encourage student participation, I set mine up in the classroom.

Once you have set up your seismograph, let it record continuously for one or two days, then save the data in a file. Before you can search for earthquakes in the data, you will need to do some processing. The exact details of the processing will depend on the software you use, but it should be fairly straightforward.

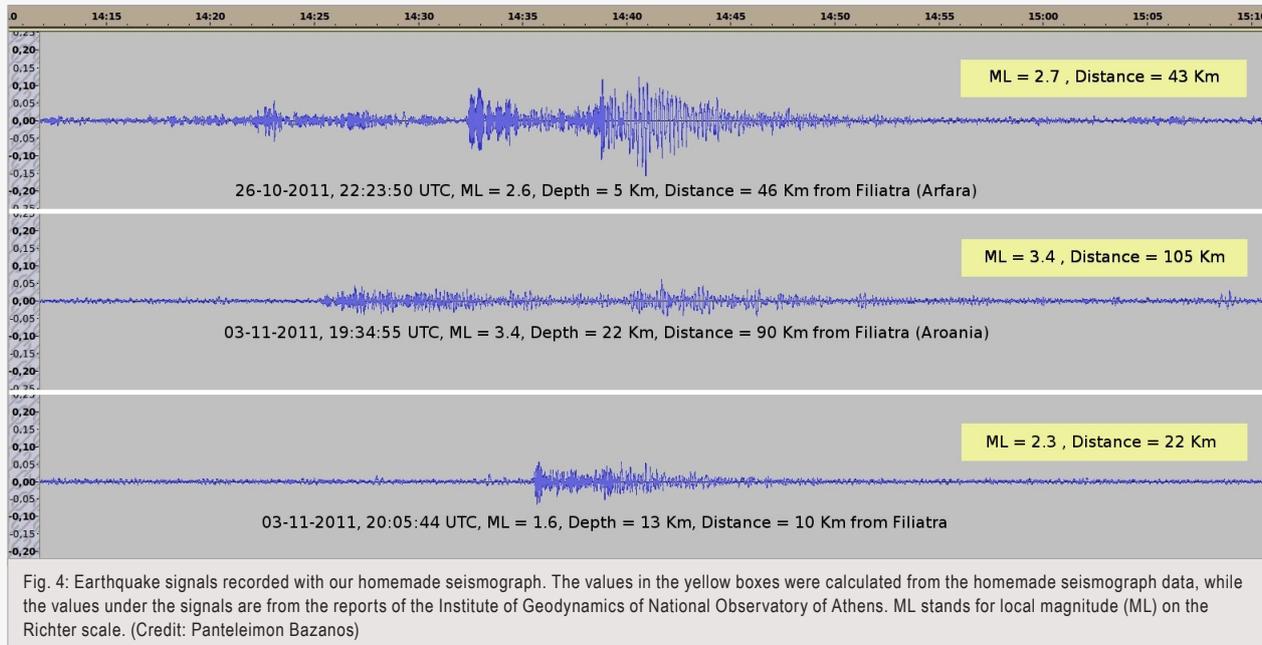


Fig. 3: Our homemade geophone (Credit: Panteleimon Bazanos)

1. Remove any *DC offset*, to remove the contribution of any DC current to the signal.
2. Amplify the low frequencies (below 100 Hz). This is the range in which you will detect earthquakes.
3. Remove background 'noise' (thermal noise, electronic noise, etc.) to make the signal clearer.
4. After that, you can search the data for patterns that indicate an earthquake.

Not all signals recorded by seismographs are earthquakes. Other, more local sources, including traffic, wind, explosions, and opening and closing doors, can cause confusion. Earthquakes often have a characteristic pattern: a small waveform followed by a large one (Fig. 1). Because this is not always the case, however, you and your students may sometimes be unsure if what you have detected really is an earthquake. The only way to be certain is to do what professional seismologists do and compare your data with the recordings made at [other seismographic stations](#).

When you are confident that you have detected an earthquake, you can calculate its magnitude (on the Richter scale) and your distance (in km) from the epicentre (Fig. 4). For that, you need only three measurements: the arrival time (in seconds) of the P and S waves, and the time at which the vibrations stop (Fig. 1). For more details, [download the instructions from the Science in School website](#).



Vibration experiments using computer speakers

I also devised experiments to simulate some aspects of earthquakes and the signals they produce – for example, how the energy of the earthquake decreases as it passes through different materials.

To do this, we used speakers and a computer equipped with a sound card and audio processing software, as before. But in place of geophones you can use old computer speakers (again with the cone removed), which can be moved around as needed in the experiments. You can use 100W / 8Ω woofers, as in the construction of our seismograph, or 3W / 8Ω computer speakers, plus the [sound-editing software Audacity](#). For more details, see steps 1, 8 and 9 in the [downloadable instructions](#).

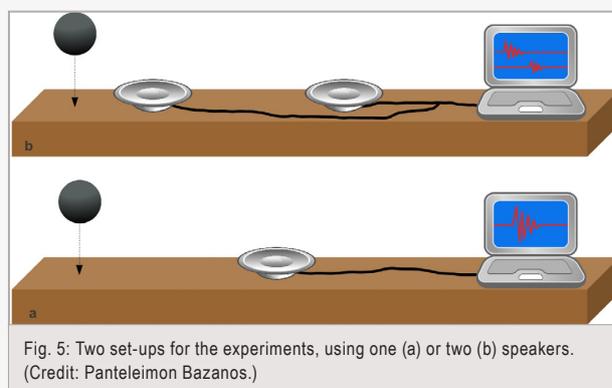
The experiments involved dropping balls from different heights (representing different energies), at different distances from the detectors (the speakers), onto surfaces made from various solid materials.

When the ball strikes the hard surface, it produces vibrations that travel through the solid – just as an earthquake produces waves that travel through Earth.

Experiment 1: The power of a shake

This activity demonstrates the relationship between earthquake power and ground movement. We caused vibrations on a piece of marble (or wood, plastic or even the ground) by dropping a mouse ball (from a computer mouse) from different heights, producing different ground-shaking powers. The amplitude of the signal depends on the power of the shake.

1. Set up the equipment as shown in Fig. 5a.
2. Drop the ball from different heights, recording the signal amplitude (Fig. 6a) in Tab. 1. It is not important exactly what distance from the speaker you drop the ball, but make sure you drop it onto the same spot each time.
3. Plot a graph of amplitude against height.
4. Discuss the graph. Your students should conclude that the more energy is released, the more the ground vibrates.



Experiment 2: Energy attenuation

This activity demonstrates the energy attenuation (decrease) as seismic waves travel through Earth's crust. We produced vibrations by dropping a 4 kg shot put (metal ball) on the ground from the same height but at different distances from the woofer geophone or loudspeaker. As the waves travel, they lose energy and the ground vibrates less. This is reflected in the amplitude of the signals.

1. Set up the equipment as shown in Fig. 5a.
2. Mark 5 distances of 1 m intervals from the woofer geophone or loudspeaker along the ground.
3. Let the ball fall from the same height (e.g. 1 m) onto the ground at each marked distance, recording the results (Fig. 6b) in Tab. 2.
4. Plot a graph of amplitude against distance.
5. Discuss the graph. Your students should conclude that the farther away the 'earthquake' is, the less the ground vibrates.

Experiment 3: Wave velocity in different media

In this activity, we investigate wave velocities in different media. As seismic waves travel through Earth, their velocity differs depending on the composition of the rocks they are travelling through. This gives seismologists and geologists important information about Earth's interior. Here, we investigate how fast vibrations travel through different solid materials.

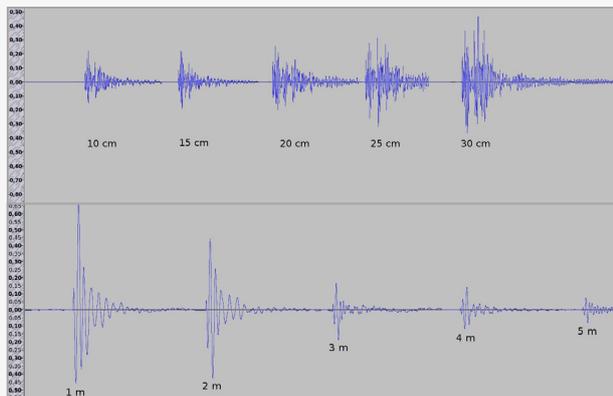


Fig. 6: a (top): The signals recorded in experiment 1. The signals were amplified by a factor of 10. b (bottom): The signals recorded in experiment 2. The signals were amplified by a factor of 4. (Credit: Panteleimon Bazanos)

We used wood, iron and marble as the materials, but any hard solid can be used. Just make sure you have the various materials available in a size suitable for the activity.

1. Set up the equipment as shown in Fig. 5b. We used a distance (x) of 80 cm between the speakers.
2. Drop a mouse ball (or other suitable object) onto the first solid material, close to one speaker, but not between the speakers. Record the times for the signal to reach each speaker (t_1 , t_2).
3. Repeat with the other materials, entering each result in Tab. 3. Work out the wave velocities using the formula: $v = x / (t_2 - t_1)$
4. Discuss the results. In which material do the waves travel fastest?

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Resources

On the website of Natural Resources Canada, there is [a brief introduction to seismographs and how they function](#).

Learn about [earthquake-measuring scales](#) on About.com.

The website of Michigan Technological University has a compact and comprehensive [guide for budding seismologists](#).

The world seismic monitor has a [visual representation of recent earthquakes](#).

For another seismograph to build at school, this one based on an ancient Chinese design, see: Kirschbaum, T. and Janzen, U. (2006): [Tracing earthquakes: seismology in the classroom](#), *Science in School* 1, 41–43

See the website of the UK's National STEM Centre for a [collection of teaching ideas for seismology](#). The materials are free but you need to register on the website to download them.

To learn how to use geographical information systems to analyze earthquakes, see: Kerski, J. (2010): [GIS: analysing the world in 3D](#), *Science in School* 15, 34–38

Marazzi, F. and Tirelli, T. (2010): [Combating earthquakes: designing and testing anti-seismic buildings](#), *Science in School* 15, 55–59

Height (cm)	10	15	20	25	30
Signal amplitude					
Distance from geophone (m)	1	2	3	4	5
Signal amplitude					
Material	t1	t2	t2-t1	x	$v = x / (t_2 - t_1)$
Wood					
Iron					
Marble					

Tab. 1 (top), 2 (centre), and 3 (bottom): Enter your results for experiments 1, 2, and 3, respectively

See the education web pages of the Incorporated Research Institutes for Seismology for more [teaching ideas about earthquakes](#).

For further teaching ideas about earthquakes, see [How to teach natural hazards in school: raising awareness on earthquake hazard](#) from the EU-funded Eduseis project.

Increasing numbers of schools are becoming involved in recording seismic data themselves. To strengthen the links between such schools in Europe, teachers are invited to apply for the second [European summer school in school seismology](#). To be held in Summer 2013 in France, it is funded by EU Comenius grants to teachers.

If you found this article inspiring, why not browse all the [science education projects in Science in School](#).

Jean-Luc Berenguer of the EGU Committee on Education, and an [expert in teaching natural hazards in school](#), comments:

“Feeling the Earth shake in the classroom is now possible by way of seismometers installed in schools. In the past couple of years, teachers have been able to bring seismology into the classroom with a lot of data in real time. This experience, beginning in the US and then in France, is spreading quickly in Europe. The development of simple devices and the design of concrete experiments, associated with an investigative approach, make it possible to instil the students, the professionals of the future, with high-quality scientific culture and education about risks. In this article, Sir Panteleimon Bazanos, shows us how teachers can motivate ‘seismology in school’ with simple and effective tools.”

Additional resources

[‘Sismos à l’école’](#), the French seismological educational network (in French)

[UK School Seismology Project](#): ‘real science with real data’

Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation – [NERA project](#)

The 2013 Geosciences Information For Teachers (GIFT) Workshop, taking place in April in Vienna, is dedicated to Natural Hazards. For more information, check the [application form and preliminary programme](#).

Remote sensing, e-learning and scientific literacy

A new learning portal for schools using satellite images

German researchers have created a new portal to help school students learn about remote sensing. In this article, they introduce the website and its teaching activities.

The project **FIS** – *Fernerkundung in Schulen* (German for 'Remote Sensing in Schools') – aims at a better integration of remote sensing in school lessons. In addition to the strengthening of natural science education and working on present questions, the use of satellite images in classrooms offers further advantages. These include a high degree of descriptiveness, a motivating effect of the imagery, as well as ways for problem-oriented working, the strengthening of spatial orientation competence, method competence, and evaluating and practice skills. Respectively, the overall objective is to teach pupils from primary school up to high-school graduation all basics and fields of application of remote sensing. For this reason, we developed a comprehensive and well-structured learning portal on the subject of remote sensing, which will facilitate teachers' and pupils' entry to the topic.



Screenshot of the learning module From Satellite Images to Maps. With a simple RGB-composition method, students are able to derive their own land use and land cover maps by classifying Landsat images (Source: A. Rienow).

Teaching materials

The learning portal's development is based on the didactic principles of moderate constructivism. Accordingly, all different learning materials of the portal are multimedia applications, thus the contents are provided through different means of coding.

The three main sections of teaching materials that form the backbone of the developed learning portal are:

Learning modules

The heart of the learning portal consists of digital and interactive **learning modules** that teach remote sensing topics following the curriculum for specific school grades. To cover different aspects of remote sensing, we developed learning modules for the subjects of geography, biology, physics, maths, and informatics. The design of the learning modules enables the user to conduct classical remote sensing analysis by using interactive tools (see figure). The

analyzes' complexity is lower than in conventional remote sensing software, thus usability as well as functionality of the digital learning modules is adapted to a pupil-friendly standard.

Research tools

To improve individual and discovery-based learning, the pupils find extensive background information provided by research tools in terms of a digital glossary (Info-Box) and an image gallery. The **Info-Box** is a digital encyclopaedia for terms and basics of remote sensing. Paying attention to the pupils' different levels of knowledge, the Info-Box is presented in two versions: beginner and professional. Additionally, the pupils can search pointedly for supplementary visual material. Searching options exist for images regarding specific regions or matching specific keywords.

Analysis tools

Individual learning is put forward by different analysis tools. The pupils have the chance to analyze single images directly. The **Sat-Calculator** helps to perform simple arithmetic calculations on digital images, for example the Normalized Difference Vegetation Index **NDVI**. Another analysis tool is the **RGB Classifier** – the pupils use this tool to learn that digital images consist of raster cells which all have characteristic colours. This colour information can be used to derive a thematic map from a satellite image. In addition to static analyzes of the land surface, we developed a tool to observe current processes of the atmosphere, the **MeteoViewer**. It shows images of the MeteoSat satellite on a daily basis, which are reloaded automatically every 15 minutes. The pupils have the option to watch the latest image or a 3- or 24-hour loop, covering either the whole Earth or Europe, to draw conclusions regarding present weather conditions.

The digital learning materials integrated into the platform allow, therefore, a high degree of interaction. Moreover, independent working and discovery-based learning is encouraged in terms of a practice-oriented approach. That way students use the added value of geodata as well as geographic-information-system and remote-sensing technology while answering specific research questions – and they communicate their hypotheses using these data and technologies as an argumentation basis to defend their decisions.

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The FIS-project is funded by the Federal Ministry of Economics and Technology through DLR, German Aerospace Centre (project no. 50EE0615). The online portal (in German) can be accessed at <http://fis.uni-bonn.de>. Teaching materials are available in English at <http://www.fis.uni-bonn.de/EnglishMaterial>.

Reference

Voß, K., et al. (2011): Remote sensing, new media and scientific literacy – A new integrated learning portal for schools using satellite images; in *Learning with GI 2011 – Implementing Digital Earth in Education*, Wichmann, pp. 172–180.