Background
In our first year of Advancing Physics AS-level we encouraged the students to undertake a wide range of projects in the Sensor Project coursework item. Many (inevitably) chose circuits to measure light intensity or temperature but a few chose to use some of the wide range of sensors that we have accumulated over the years. One student located a pH probe/conductivity meter and planned to calibrate it as part of a salinity meter. In the event the sensitivity of the probe was such that the smallest concentration of salt caused the output to saturate. Some two hours into a five-hour exercise he decided to construct his own salinity meter based on the probe.

As far as we could ascertain the probe was no more than two electrodes (albeit platinum) and a chamber into which the solution could flow. An ammeter completed the basis of the instrument. Within half an hour a macroscopic version of the probe had been constructed at minimal cost and went on to provide the basis for a good project. The student pressed into service a small, transparent plastic box and aluminium cooking foil for the electrodes. Crocodile clips came in for a bit of a pounding in such a hostile corrosive environment but we buy them in bulk and they were still usable.

It struck me that this was an inexpensive GCSE Investigation with lots of scope – a good number of variables and a source of reasonable but ‘messy’ results – and a blessed relief from the ‘resistance of a wire’ investigation whilst sharing much of its theoretical foundations. A word of caution: if p.d. is the selected variable be aware that a graph of current against p.d. does not pass through the origin—we found it to be linear but crossing the p.d. axis—some background research into voltameter cells may help to explain this. If p.d. is not selected as the variable it is important (for full marks) that measures are taken to keep the p.d. across the solution constant.

Apparatus required
- Plastic container (sizes from 15 cm × 5 cm × 5 cm down to 5 cm × 3 cm × 2 cm have been found to give reasonable results). Ferrero Rocher chocolate containers work well and are transparent, allowing the solution to be readily observed. Small component trays also work well and require much less salt.
- Aluminium cooking foil for electrodes (copper electrodes also work)
- Crocodile clips (which enable contact with the foil and secure it against the edge of the container)
- Power supply (dry cells have worked well: 1.5 V to 6.0 V)
- Rheostat/Variable resistor (value depends on size of container and depth of solution). The main purpose of the variable resistor is as a ‘ballast’ resistor to allow a constant potential difference (p.d.) to be maintained across the solution.
- Switch to break circuit between readings
- Connecting wires six or seven per experiment
- Mass balance 0.1 g resolution should be sufficient
- Ammeter Digital ammeters with multiple ranges are ideal
- Salt About 20 g per experiment if large boxes are used

Teachers’ notes
This was a worthwhile and rewarding exercise for most, if not all, students. Given that the apparatus is fairly readily available it makes an interesting alternative to the ‘resistance of a wire’ investigation whilst sharing much of its theoretical foundations. A word of caution: if p.d. is the selected variable be aware that a graph of current against p.d. does not pass through the origin—we found it to be linear but crossing the p.d. axis—some background research into voltameter cells may help to explain this. If p.d. is not selected as the variable it is important (for full marks) that measures are taken to keep the p.d. across the solution constant.

Sample results
The preliminary results obtained by a Year 10 student, Daniel Wilson at Christ College Brecon, are shown in table 1. There is plenty of scope for analysis here. The power source in this instance was 4 ×1.5 V dry cells.

A second student, Cheryl Wong, opted to vary the area of the aluminium electrodes. Her results
Other students in the same group investigated the effect of temperature and distance between electrodes.

<table>
<thead>
<tr>
<th>Size of electrodes</th>
<th>Average current/A</th>
<th>Dimensions/cm</th>
<th>Area/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 × 1.0</td>
<td>3.0</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>3.0 × 2.0</td>
<td>6.0</td>
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<tr>
<td>3.0 × 4.0</td>
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</tr>
<tr>
<td>3.0 × 6.0</td>
<td>18</td>
<td>0.51</td>
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<td>3.0 × 8.0</td>
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<td>0.69</td>
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<tr>
<td>3.0 × 10.0</td>
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<td></td>
</tr>
<tr>
<td>3.0 × 12.0</td>
<td>36</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>

Tony Reeves  
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**Lesson Plan**

Let the pupils do the work

This is a teaching idea I had when desperately busy and lacking in energy. It involved getting pupils to do all the work, have some fun, get their minds on some physics and learn something. I did very little—dare I say it, ‘I facilitated their learning’. I promise not to use the F-word again, but I have definitely used the following format for many lessons.

I was teaching 13 year-old pupils about ideas and evidence surrounding the heliocentric model of the solar system. All the pupils had access to computers, so I just wrote down the following words on the board and told them to search the internet for suitable descriptions and explanations and to identify a linking theme:

- Retrograde motion
- Mars
- Phases of Venus
- Heliocentric
- Geocentric (I avoided the word model, as pupils have had ‘problems’ on the internet with this word before!)
- Galileo

I had already introduced the topic of ‘space’ earlier in the week, but I told them nothing about these key words. They really had to find out the linking theme themselves.

For the next 20 minutes they were totally engrossed. One of the students had found a list of about six sites referring to retrograde motion, some involving applets and animations. I connected her computer to a data projector and stopped the activity briefly to show the rest of the pupils what to look at. The next aim was to look at each site and decide which one explained retrograde motion best. I still refrained from telling them what retrograde motion was. I also emphasized that their opinion mattered, that I valued their judgment. This was not a deliberate bit of psychological manipulation to get them all on task. I really meant it. I wanted to know which sites explained the idea best to them, so that I could save the site in ‘my favourites’ and use it in the future. In the next 20 minutes they were all focused on trying to understand the idea, but the decision was easy for most of them to make—as soon as the idea ‘clicked’ then it was obvious which site had been responsible for this conceptual shift.

We eliminated those sites with too much to read, narrowing the sites down to a choice of four. One student demonstrated these animated sites using the data projector. The great things about this lesson were:

- Pupils’ minds were on the physics;
- They felt their opinions were being valued (and they were!);
- There was an element of problem-solving and competition because they had to find a linking theme between different words;
- They voted as a group and discussed in the class,