Expertise in Electric Circuits
Relies on Brain Areas Involved in Inhibition

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Introduction
- Students have erroneous and persistent conceptions about electric circuits (Çepni & Keles, 2006; Periago & Bohigas, 2005).
- Conceptual change is a widely explored domain of research in science education since the 80's, but there is no consensus on the processes underlying conceptual change yet (diSessa, 2006, 2008).
- Discovering new information using neuroimaging can provide useful insights for understanding conceptual change.

Hypothesis
- Inhibition might play a central role in certain types of learning (Houdé, 2004) – for instance, in situations where learners must overcome spontaneous and inappropriate strategies or answers.
- One study suggests that inhibition might play a role in conceptual change in mechanics (Dunbar, Fugelsang, & Stein, 2007).
- Studies related to inhibition show activations in the anterior cingulate cortex, the prefrontal cortex and the medial frontal cortex (e.g. Bush et al., 1998; Houdé et al., 2001, Menon et al., 2001). If inhibition plays a role in conceptual change, brain areas related to inhibition will be more activated for experts than for novices.

Method
- fMRI is used to see if inhibition networks play a role in conceptual change.
- T2* images are obtained with a 3T Siemens TRIO TIM (12 channels, TR = 2.0 s, whole brain scanned).

Participants
Groups of participants differ in their education and conceptions about electricity.

<table>
<thead>
<tr>
<th></th>
<th>Novices</th>
<th>Experts</th>
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<tbody>
<tr>
<td>N</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Age (years old)</td>
<td>19 ± 3.5</td>
<td>22 ± 3.0</td>
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<tr>
<td>Gender</td>
<td>Male</td>
<td>Male</td>
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<tr>
<td>Education</td>
<td>bacalaurreate students</td>
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<td>Physics</td>
<td>humansities students</td>
<td>physics students</td>
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<tr>
<td>naive conceptions (&gt; 50 %)</td>
<td>scientific conceptions (&gt; 50 %)</td>
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Task
- 12 stimuli of naive circuits
- 20 stimuli of scientific circuits
- 20 stimuli of control circuits
- 20 stimuli of a fixation point

Figure 1. Brain regions related to inhibition.

Analysis
- There are only a few differences between experts and novices when they evaluate scientific circuits and control circuits. Novices show greater activations than experts in the left dorsolateral prefrontal cortex when they evaluate both scientific and control circuits. Experts show higher activations than novices in the right angular gyrus when they evaluate control circuits.
- But when they evaluate naive circuits, experts show greater activations than novices in many regions such as the anterior cingulate cortex, the medial frontal gyrus and regions of the prefrontal cortex (see figure 4).

Results

Discussion
- Experts need more cerebral resources to evaluate naive circuits, although one could think it is easier for expert to answer than for novices.
- Experts seem to rely primarily on inhibition networks when they evaluate naive circuits.
- This could mean that experts have not change their naive conception (one wire can light a bulb) and have to inhibit it to answer correctly.
- Data do not support conceptual change models postulating that conceptions are erased or transformed into something else after conceptual change.
- Data are compatible with conceptual change models that postulate that conceptions are build with cognitive resources that still exist after conceptual change, or with models that postulate a cohabitation of conceptions.

Conclusion
- When they evaluate naive circuits, experts show more activations in brain areas related to inhibition.
- Thus, student’s conceptions might not be transformed into something else after conceptual change but rather might be inhibited.
- Future studies: a better characterization of expertise in electricity might allow comparison and evaluation of science teaching methods.