**​Instructional Plan**

**Object**

Pop-up toaster

**Audience**

The audience for this instructional video is 5th-9th graders who are either curious about how things work, or interested in engineering. The prior knowledge expected of this audience would include: power outlets provide electricity, electricity runs through wires, and electrified wires get hot and glow. This audience is expected to have prior experience making toast or Pop-Tarts™.

Possible misconceptions anticipated from this audience include the type of heat that toasts bread, as well as the confusion or perceived mystery around the source of under- or over-toasted marks in the toast produced. This audience may have a misconception that the bread is toasted by direct heat, like in a pan or griddle, when in reality the bread is toasted by radiant heat, like in an oven. This audience may also be confused by toast with markings that look over- or under-done, thinking either that this indicates that their toaster is not getting hot enough, or that their toast is made by bread touching the wire heating elements directly. In reality, this occurrence is caused by the type and thickness of the metal that makes up the internal cage, which can result in shielding or scorching bread in certain areas.

**Technical Plan**

The instructional approach used in this video is guided discovery. Guided discovery can be thought of as an invent-then-tell approach. Learners will be asked a series of five questions throughout the instructional video. In keeping with the invent-then tell paradigm, learners first decide on an answer and then receive corrective and velocity feedback. If students get the correct answer, they receive textual correctness feedback and the video proceeds. If students choose a wrong answer, they receive textual feedback indicating why their answer is incorrect and are prompted to try the question again. After completing each question, the video explains the mechanism underlying the correct answer using organizational graphics and animations.­­ When a question is asked, the video pauses, and an overlay with the answers appears in a simple animation on top of the video to obscure extraneous content. Learners click an answer in the overlay to receive textual feedback (which replaces the answers on-screen) and proceed or repeat the question.

Unlike the rest, the first question presented to learners is an open-ended prompt for students to conjecture how a toaster works. This question serves the dual purpose of scaffolding use of the interface by focusing the user’s attention on the clickable answer bubbles, and fostering an open-ended opportunity to invent for themselves a mechanistic explanation prior to receiving explicit instruction.

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# Difficulty Getting Started

Selecting an object, questions, and misconceptions was very difficult, in large part because the line between how something works and how you ought to use it is fuzzy (one generally has immediate implications for the other). For example, we considered pickles as our everyday object and initially thought this sounded great: they are commonplace, and require the interesting mechanism of fermentation in order to exist. But we ran into a problem: Pickles don't *do*anything interesting. What is interesting, and what we had hoped to talk about was how a pickle is made. Even though this is an interesting physical process with an underlying physical mechanism, we were concerned that we would fail to meet the requirements if our object was too process-like.

Even once we had settled on the object of a toaster, which unambiguously *functions*via physical mechanisms, the details of our questions still ran into this problem. Let's contrast two very similar questions:

"Do toasters have a safeguard that prevents you from shocking yourself if you stick a knife into them?"

"Can I safely stick a knife in a toaster to retrieve toast?"

It seemed to us that the first question is one of underlying mechanism: some people appear to think that it is safe to insert a metal object into a toaster because they suppose the toaster to have a way of protecting them from shock. The second question is procedural. It is about whether it is wise to extract toast with a knife. Yet they are asking very nearly the same thing! Our impression was that the former question would be acceptable and the latter would be penalized for failing to meet the assignment's requirements. We thus spent an inordinate amount of time trying to find questions that were completely, unambiguously about mechanisms, rather than procedures.

# Easy Parts

Domain Research on how toasters work was relatively easy.

​Technically, adding and removing elements on the screen based on the timing of the video and the user's clicks was relatively simple.

# Future Improvements

Technical shortcomings: The experience breaks if the user pauses the video manually, plays it at a different speed, or skips around​. Fixing this would require a change in the structure used to pause and unpause the video, or disabling these elements of user control. Future work should determine whether permitting these actions is desirable for learning and either enable them without breaking, or simply disable them.

Another future improvement could be use branching paths through the video to give more detailed feedback about specific misconceptions. So learners who chose wrong answers could receive not only textual feedback and a general description of how the underlying mechanism works, but they could additionally receive a specific excerpt that rectifies their misconception in greater detail.