ACORN Physics Tutorials Facilitator Guide

ACORN Physics Tutorials support learning environments that Attend to Conceptual Resources in Physics. Conceptual resources are potentially generative student ideas: "seeds of science" that can grow toward sophisticated understandings with support and cultivation. ACORN Physics Tutorials support students to construct their own models for physics concepts. Students engage in three main activities as they iteratively build a model they can use to explain and predict phenomena:

Gather: Students respond to conceptual physics questions that research has shown to consistently elicit generative student ideas about specific physics topics (e.g., wave propagation, dc circuit behavior, collisions).

Articulate: Students express their ideas more formally, often as a set of rules.

Apply: Students apply and test their models for a phenomenon.

How do I implement ACORN Physics Tutorials?

- Use these tutorials in person or in synchronous online classes in a 50-90 minute period.
- Arrange for students to work on the worksheets collaboratively in groups of 3-4.
- Plan for intermittent but regular instructor engagement with every group: If possible, there should be one instructor for every 2-4 student groups. Near-peer facilitators (LAs or TAs) are helpful.
- Instructors should prepare for both the general approach taken by the worksheet and the specific worksheet questions in a preparation session that takes place before class.
- The worksheet should not be graded, so that students can explore a variety of ideas without feeling pressure to get the right answer.

What should I expect students to do during an ACORN Physics Tutorial, and how can I help?

- Students will generate many novel ideas and questions. Instructors can:
    - Notice and elevate their original ideas and questions.
    - Revoice their ideas and questions back them.
    - Ask clarifying questions to help them connect the dots.
- Students will experience vexation points, "critical moment[s] when the[y] articulate an inconsistency or gap in their understanding [that] kicks off the sensemaking frame." [1] Instructors can:
    - Suggest analogies, thought experiments, and contrasting cases.
    - Choose questions or observations to elicit additional conceptual resources.
- Students will be motivated to answer their novel questions, but will find this challenging. Instructors can:
    - Help students narrow their questions to be answerable with the resources they have.
    - Suggest experiments to test/explore students' questions.
- Students will wonder whether their ideas are idiosyncratic or shared. Instructors can:
    - Encourage student groups to share ideas with each other.
    - Facilitate sharing by asking questions about how students' ideas connect to one another.
    - Connect students' own ideas or models with canonical models and concepts.

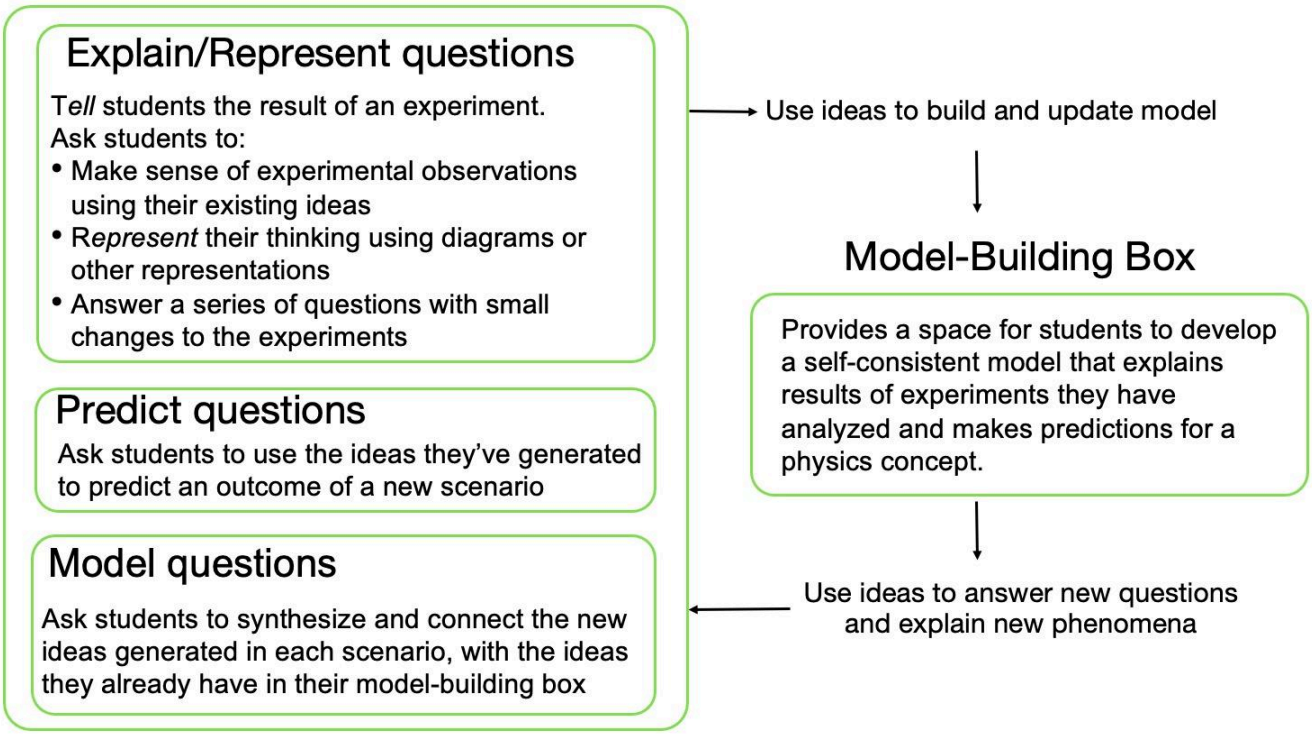
What materials come with ACORN Physics Tutorials?

- *Worksheets* for students (editable and pdf)
- *Instructor guides,* including common student ideas about each physics topic
- *Periscope video lessons* for instructor training, highlighting how ACORN Physics tutorials elicit student thinking and illustrating instructor moves that effectively support students' progress

- *Pretests* and *post-tests* to prime and assess student thinking

How does an ACORN Physics Tutorial work?

ACORN Physics Tutorials guide students through the process of developing a model, or set of rules, that explain observations and make predictions for a particular concept. Small groups of students work through a series of questions to prompt their thinking. Throughout the worksheet, they are asked to keep track of the central ideas and concepts that they use to explain and predict by writing ideas and rules in a model-building box. By the end of the worksheet, each student's model-building box should contain a self-consistent model that explains the results of the experiments students have analyzed. The goal is for each student to develop a consistent set of rules, not for all students to develop the same set of rules. Rules may be simple or complex.



Example model-building box completed by a student:

Model-Building Box: Circuits

"Bulbs light up when there is a current going through the bulb. When there is a difference in potential, the positively charged electrons can flow through the bulb with a current that is proportional to the potential difference divided by the resistance of the bulb. The current flows from high to low voltage. This means that the potential difference on either side of the batteries and resistors that are in a circuit is what dictates the direction of current flow for the whole circuit.

With this being said, different bulbs within the same circuit can have different levels of brightness due to having different amounts of current flowing through them. In a series circuit with identical batteries and bulbs, the current is equally distributed among all the bulbs. The voltage is based on adding the sum of all the voltages from the batteries and the resistance is based on adding the resistance of each of the bulbs. In a parallel circuit, you could have a wire after a bulb that splits current equally down two different pathways and therefore those two bulbs that are using current that has been split will be dimmer than the first bulb with access to the full current."

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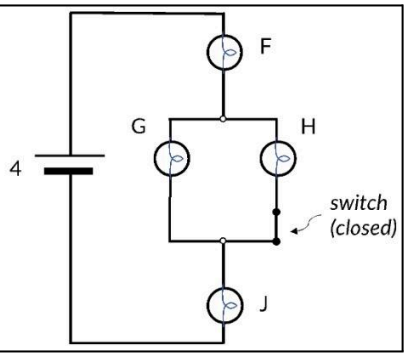
These tutorials ask students three different types of questions:

1. **Explain/represent questions** *tell* students the result of an experiment or a law of physics and then ask them to generate ideas to explain why that is the result. They may also ask students to represent their thinking—or the phenomenon they've just explained—using diagrams or other representations. Students may be given a series of experiments where small changes are made, and asked to generate multiple explanations and refine their ideas based on these.

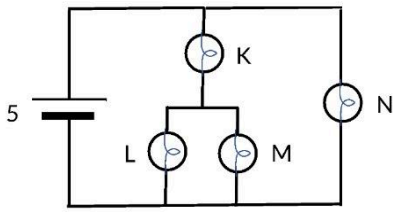
> In the circuit at right, the switch is initially closed.
>
> When the switch is closed, the ranking of the brightness of the bulbs is $F = J > G = H$. Explain this observation in terms of current and show your reasoning in a diagram.



These questions elicit students' ideas about key physics phenomena. Starting with the result rather than a prediction provides opportunities for students to be right and to practice using tools to represent their own thinking. Students' representations provide opportunities for instructors to quickly visualize how students are thinking.

2. **Predict questions** ask students to use the ideas they've generated so far to predict an outcome of a new scenario. Students are not asked to predict until they are likely to have enough of a model to predict correctly.

> Use the ideas you developed in parts A-D to rank the brightness of the bulbs in the circuit at right.



These questions give students practice applying their model and make visible places where the model needs to be refined.

3. **Model questions** ask students to synthesize and connect the particular ideas they have been working with, with the ideas they have in their model-building box.

> Revisit the model-building box on page 1. Can you use only the ideas that you've written in the box to explain why bulb A is brighter than bulb D or E? If not, either modify or add to the ideas there so that the box represents the ideas you are using to explain this observation.

These questions guide students toward a consistent conceptual model for the set of phenomena presented in the worksheet.

What is the question style?

Explain/Represent

Do you want to ask follow-up questions?

- No, I want to quickly get a sense of what's coming up for students → **Observation List**
- Yes, I want to know more details → **Non-fixing conversation**
- No, I want to quickly flag an idea so students can return to it later → **Idea parking lot**

Observation List

On a sticky note or piece of paper, students write three things that stand out (e.g., as exciting, interesting, sensible, or puzzling) about an observation, experiment (like one of the scenarios in an ACORN tutorial), then compare and discuss their lists. Instructors may add their own list.

Idea parking lot

Instructor or student write a student idea in the "parking lot" on a whiteboard or paper (this could be a space on the front page of the tutorial) to return to later.

Non-fixing conversation

One student speaks for 2-5 minutes about a question or scenario. Another student or the instructor asks follow-up questions to learn more about the other person's ideas. Do not ask questions to guide, critique, or challenge their thinking. Example questions include:

- How do you make sense of this?
- What experience is your thinking is drawing on?
- Can you give an example?
- Will you draw a diagram to illustrate your ideas?

Model

Is energy relevant?

- yes → **Energy story**
- no → **Energy story**

Energy story

Students collaboratively decide on and diagram or act out the "story" of various energy forms and the objects they are associated with and the energy transfers and transformations for a scenario they are thinking about.

Idea map

Instructor writes several student ideas on the whiteboard. Students add arrows to connect ideas and write how ideas relate and when they are useful.

Diagram diamond

Each student draws a diagram to model an experiment in each corner of the same paper, discuss the merits of their diagrams, and draw a consensus diagram in the middle.

Predict

Where are students in their completion process?

- They are working on models and want to check an idea. → **Thought experiment**
- They have clearly-articulated models to test → **Testing experiment**

Thought experiment

Instructor poses a new scenario or experiment and students explain what will happen. Use a thought experiment to:

- Affirm: an experiment where students' ideas/model gives a correct prediction.
- Extend: an experiment where the idea/model is fruitful, but not enough to predict or explain the outcome on its own.
- Define the limits of applicability: an experiment where the idea/model leads to an incorrect prediction.

Testing experiment

Instructor suggests several possible experiments, students decide which is best for testing a part of their model and construct alternative hypotheses.

This instructor resource is inspired by K. Wingert and A. Rhinehart, STEM teaching tools talk activities flowchart (2016);
Non-fixing conversation format is inspired by Hunter Close, and we acknowledge Carl Rogers for inspiring the non-fixing mindset.
Energy story inspired by Scherr et al, https://doi.org/10.1103/PhysRevSTPER.8.020115