Facilitation Strategies for Inquiry-based, In-class Activities using PhET Simulations http://phet.colorado.edu

Here we describe effective strategies for facilitation of activities using PhET simulations (sims) in elementary and middle school classrooms. These strategies are derived from observations of teachers using a range of PhET sims in a classroom setting. These strategies are not meant to be strict "step-by-step" directions, nor do they include all possible effective strategies. Rather, these strategies can be adapted to the particulars of different grades, teacher preferences, and classroom environments.

Overall, this collection of strategies aims to support inquiry-based learning. Through the use of PhET sims, students explore new ideas, take ownership of their own learning, and cultivate positive attitudes toward science.

Outline:

1. **Goals for Teachers:** Describes what teachers can achieve through implementation of these strategies.
2. **Facilitation Objectives and Strategies:** Introduces 6 objectives of sim-based activity facilitation and suggests specific facilitation strategies.
3. **Monitoring and Measuring Student Learning:** Discusses strategies for monitoring understanding throughout sim use, and the optional use of written assessments.
4. **Example of Activity Facilitation Sequence:** Demonstrates facilitation strategies and sequencing within an example lesson.
5. **Preparation:** Provides a summary of important preparation steps, including ***creating the lesson***, ***preparing the classroom***, and ***preparing to teach***.
6. **Teacher reflection:** Suggests approaches for reflecting on teaching and learning, including a rubric for characterizing lesson qualities.
7. **Supporting PhET:** Describes opportunities for furthering the PhET project by providing feedback, sharing effective teaching approaches, or describing evidence of effectiveness.

Information about creating activities and activity sheets is provided in the Creating PhET Interactive Simulations Activities

Goals for Teachers

Teachers will …

- Create a student-centered classroom by …
  - Hearing and valuing student ideas
  - Promoting student agency – students actively driving their learning
  - Encouraging and guiding student inquiry
  - Being a co-participant in the inquiry process
  - Building on students' prior knowledge

- Foster a supportive, goal-oriented learning environment by …
    - Valuing and addressing multiple goals - content, process, habits of mind, interest, etc.
    - Being prepared to address common student ideas/thinking and confusions
    - Adapting activities to their environment and their students (e.g. for varying learning goals and education levels)
    - Implementing 'checks for understanding' in order to assess student learning and drive instruction
    - Being responsive by flexibly adapting to emergent student ideas
- Bring their experience, professionalism, and knowledge of their students to designing, implementing, and improving activities, implementation, and sim design.

Facilitation Objectives and Strategies

Using PhET sims in an inquiry-based class supports, and is supported by, the following broad facilitation objectives. Within each objective, we highlight example facilitation practices.

1. **Make learning objectives explicit and meaningful to students.**
    a. List learning objectives at the top of each activity and have students read them aloud.
    b. Facilitate class discussion to clarify the meaning of the learning objectives, to connect to past and future goals, and to increase investment.
2. **Motivate students through real world connections and questions to drive inquiry.**
    a. Help students relate what they learn during the sim activity to other activities – e.g., activities at beginning of class (e.g., hands-on), on other days (e.g., what they did last week), or in their everyday lives (e.g., what they do at home or on the playground).
    b. Prompt students to question what they see every day, such as why a straw appears broken when seen through a glass of water or why the sunset is red, and use these questions to motivate discovery through the sim activities.
3. **Develop students' ownership over learning and use of learning tools (i.e., PhET sims).**
    a. Allow time for "free play" at the beginning of an activity to help students become familiar with the sim and take ownership over it as a learning tool.
    b. Students should be in control of their own computers. Avoid taking direct control of a student's computer, for instance to show the students how to change something in the sim. Instead, try to ask questions that will lead the student to figure it out on their own.
    c. Use ideas elicited from students to inform others about how to use the sim. Students usually figure out a majority of the controls and scenarios in a sim during the initial "free play" time, and they can share ideas with each other.
    d. Avoid showing students what to do with the sim on the projector or SMART Board, especially before the "free play" time. It may be necessary to demonstrate something if all students are having difficulty, but as much as possible let students figure things out for themselves or from their peers.

e. When possible, designate either 1 or 2 students per computer. One student per computer allows students to explore the sim in their own space while sharing their ideas with their neighbor. Two students per computer can increase student-student collaboration and discussion. Three or more students is workable, but less ideal, because one student may not get much time "at the wheel" of the sim.

4. **Foster a student-centered learning environment and give students voice.**
   a. Ensure students are active participants in both teacher-student and student-student discussions.
   b. Give direct instruction on sim use only when students are unable to figure it out on their own. Play time at the beginning usually allows students to learn nearly all the controls in a sim, which frees up time during class to focus on concepts, rather than sim usage specifics.
   c. If students do have difficulty with the sim, preferably use student-student interactions and class discussion to facilitate student-led discovery. A useful strategy is to circulate the room watching students use the sim. If one or two students have figured something out that others find difficult, provide opportunities for these students to share ideas on usage with the entire class.
   d. Listen to student conversations and use these ideas for promoting class discussions. By listening to individual conversations during group work, teachers will have a better idea of what students are going to say in class discussions, and be better prepared to facilitate these discussions by drawing on student ideas.
   e. Capitalize on unexpected learning opportunities. The richness and flexibility of the sims will often lead to student discoveries and student questions that were not anticipated, but make for a good activity or discussion. Teachers should feel free to improvise and take advantage of these moments, using the many features available in the sim to help facilitate these unanticipated discussions.
5. **Promote student engagement by soliciting student ideas, having students externalize their ideas, and providing opportunities for students to practice scientific conversation.**
   a. Invite students to share their ideas with the class using a SMART Board or projected sim, making their ideas visible and promoting discussion.
   b. Ask several students for ideas in whole class discussions, encouraging student-led debates, idea building, and idea refining. This approach is most successful in classrooms where students view, and are comfortable with, being wrong as a healthy part of learning. Some common techniques include: Debating, Think-Pair-Share, Answer-Stems ("I agree with …, but disagree with …"), etc.
   c. When a teacher uncovers a misunderstanding or incomplete understanding, encourage further sense making by allowing students to use the sim to find the correct answers, e.g., with the prompt "Show me how you found that"?
6. **Address diversity of learning objectives:**
   a. Attend to broad learning objectives and 21st century skills, in addition to content-specific objectives. For instance: designing science experiments; drawing inferences from evidence; constructing arguments; discussing the nature of models, their

limitations and advantages; communicating ideas; and reflecting on the nature of science.

b. Use extension activities to provide differentiated learning opportunities.

Monitoring and Measuring Student Learning

1. **Monitor student understanding and foster metacognition**
   a. Integrate 'Checks for Understanding' throughout the lesson, making student thinking visible to the teacher, helping students monitor their own understanding, and allowing for responsive instruction. Techniques may include using clicker questions, calling on students to share out responses for specific questions listed on the activity sheet or verbally posed by the teacher, or circulating to review student responses on their activity sheet.
   b. Use a written post-assessment (or "post-lab"), a class discussion, or other 'Checks for Understanding' at the end of the sim activity to gauge student achievement of learning objectives, using the results as a formative assessment to inform further instruction.
   c. Have students review their learning as a class discussion (e.g. by reflecting on the learning objectives, by reviewing and discussing the "post-lab" questions, etc.)
   d. Provide opportunities for students to reflect on the sim activity (e.g. what new understandings did they gain, what connections do they make to real life, what did they find confusing, what did they find helpful)

2. **(Optional) Track growth and mastery of learning objectives with written assessments**

While not required, some teachers find it useful to use written assessments to measure mastery of learning objectives. Here we provide some strategies for implementing this approach:

Pre- and post-assessments (often titled "pre-lab" and "post-lab" to reduce student anxiety) can be designed to measure progress towards achievement of the learning objectives. **The pre-assessment** serves as a measure of students' initial ideas and what they already know before starting the activity. Teachers can use this insight into students' initial thinking to inform their facilitation of the activity. **The post-assessment** serves as a measure of students' mastery of the learning goals. Teachers can use this student work to facilitate follow-up discussions and guide next steps toward achieving mastery.

Teachers who want to **track learning gains** use both the pre-assessment and post-assessment. Teachers who are primarily interested in **tracking mastery** may prefer to use only the post-assessment.

Administration:

a. If used, the "pre-lab" is generally administered before starting the activity, often at the beginning of the class as a "Do-now" or the day before. The "post-lab" is administered after the activity, sometimes the following day if necessary.

b. These assessments measure individual student achievement. As such, students should complete the "pre-lab" and "post-lab" on their own without help from peers, the sim, or other resources.
c. The "pre-lab" can sometimes cause anxiety for students. Reassure students that the pre-lab is just to find out what they think, that it's OK if they don't know all the answers, and that they should try their best. Assure students that they will learn what they need to in the activity.

Example of Activity Facilitation Sequence

Here we step through an example of a sim-based activity lesson and the facilitation sequencing, where the facilitation strategies support achievement of the objectives described above.

1. (Optional) Students are administered pre-lab or an engaging 'Do Now'.
2. Teacher introduces the topic through discussion or presentation to motivate and build connections. Teacher approaches vary, sometimes using:
    - a presentation on board or with projector,
    - a hands-on activity, or
    - a class discussion around the topic.
3. Students open the sim and play freely for 3-10 minutes, with duration depending on overall class period and sim richness.
    - Teacher frames this activity as free exploration time, where students use the sim, share ideas with each other, and discover.
    - Teacher provides no explicit direction as to how to use the sim. Students figure this out.
    - Teacher circulates the room, observes what students are doing, encourages scientist-like behavior through narrative-style comments (" I see [Student] discovered [X]") and through questioning ("Why do you think that is?"), makes mental or written notes of student ideas to inform later facilitation, and notices any difficulties with sim usage.
4. Teacher may facilitate a whole-class discussion, asking students what they have found and inviting them to share ideas verbally or to demonstrate ideas using the sim projected at the front of the room.
5. Teacher hands out the activity sheet, and has students read the learning objectives aloud. The teacher …
    - has a different student read each learning objective,
    - may have students try to explain terms or meaning of objectives, or may have them identify terms they don't know but will discover during the activity, and
    - if students have difficulty, teacher may guide the class toward understanding.
6. Students begin guided activity sheet.
    - Students usually work in groups of 2, discussing and sharing ideas with each other.
    - Students can have their own computer or share one.
7. Teacher circulates, interacting with individual students and groups.

- Teacher asks students questions about concepts, integrates 'Checks for Understanding', and gathers student ideas. This interaction helps inform when and how to facilitate whole class discussions.
- Teacher may use these discussions as launching points for class discussions.

8. At some point during the activity, the teacher facilitates a whole-class discussion, often soliciting findings or ideas from students, checking for understanding, and facilitating discussion around a particular concept.
    - The stopping point is often pre-planned, but may be initiated by a spontaneous student question.
    - Teacher asks several students for ideas, and may ask students to respond or elaborate on another students' ideas, practicing scientific reasoning, communication, argumentation, and/or debate.
    - Students may answer and explain from their seats, or students may go to the SMART Board or projected sim, using the sim to help communicate ideas or demonstrate to the class. Teacher may ask this student questions, or ask class to explain or reflect on this student's ideas or demonstration with the sim.
    - Teacher is checking for understanding, and using findings to inform instruction.
9. Students go back to activity. Teacher stops for whole class discussions again at appropriate points (repeat #6).
10. End of guided activity.
11. Teacher provides opportunities to reflect on learning.
    - Teacher may administer a written post-lab that measures individual student achievement of learning objectives.
    - Teacher may solicit student reflections on and new understandings related to the learning objectives – e.g. verbally or as a 'Do Now' the next day. Teacher may facilitate class discussion synthesizing students' ideas about what was learned.
    - Teacher may solicit student ideas about connections to what students did in earlier classes, what they may be doing in the future, or to their everyday life.
    - Teacher may lead whole class discussion of post-lab questions, gauging student mastery and using this opportunity to help students monitor their understanding and to inform future instruction to achieve mastery.

Preparation

Creating the lesson

PhET's "Activity Sheet Design Guidelines" provides guidance and insight on preparing sim-focused activities and accompanying activity sheets. In general, the process includes selecting the standard(s) to be taught, choosing a PhET sim, identifying 2-3 specific measurable learning objectives, and designing the activity sheet.

Preparing the classroom

1. Consider the available technology. Preferably, classrooms will have 1-2 students per computer. If fewer computers are available, consider forming multiple stations where

the PhET activity is one station or facilitating the activity with one sim projected at the front of the classroom.
2. Arrange the classroom to support student-student collaboration.
3. If possible, project the sim on a large screen or SMART Board and allow for students to come up and control the projected sim.
4. Check student computers ahead of time.
    - Make sure computers are charged, updated, and ready for use.
    - Make sure the sim runs correctly on computers.
    - If internet connectivity is unreliable, the sim can be downloaded and run directly from student computers. Use the "Download" button on the sim page and copy this file to each computer's desktop. Or install a local copy of the entire PhET website.
    - Contact PhET staff if sim problems arise (phethelp@colorado.edu).

Preparing to teach with a sim

Preparation is key to make sure the sim-based activity will go smoothly.

1. Play with the sim. The more familiar teachers are with the sim, the better they can assist students in trouble spots and facilitate spontaneous discussions. This familiarity …
    - allows teachers to "see what students are thinking" by observing their use of the sim, providing useful insight into student ideas without interrupting students' exploration and discussions with their partners.
    - helps teachers anticipate what students will say and do.
2. Be sure to go through the activity as a student. This process reveals any issues with the activity sheet or the sim. Consider …
    - creating side-bar notes (e.g. highlighting potential points for sharing out or checks for understanding, or noting possible discussion questions). These notes provide a useful document to reference during class and a place to record questions that arise.
    - creating an answer key.
3. Keep a back-up plan, in case of unexpected technology failures.

Teacher Reflection

While it is often challenging to make the time, reflection is a critical step in the teaching cycle that helps advance teaching practices, activity design, and student learning. Teachers should consider …

- reflecting on how the sim-based activity went for both themselves and their students, ideally the same day or the next day;
- inviting a colleague to serve as a reflection partner, where she/he observes the classroom when teacher uses a sim and the partners reflect on the use together; and
- using a reflection rubric, that serves to highlight and remind teachers of the teaching elements and student actions that they are trying to achieve. We have developed the **'PhET Reflection Rubric'** which provides a basic rubric aligned with the teaching and student practices outlined above

Supporting PhET

Here are opportunities to help advance the PhET Project by providing feedback, contributing effective teaching approaches, describing evidence of effectiveness in your environment, or helping to sustain the project. **Contact PhET at: phethelp@colorado.edu**.

1. **Technical problems.** Any technical problems – including simulation bugs, website failures, computer incompatibilities – with the sim should be reported back to PhET researchers as soon as possible.
2. **Simulation feedback.** If teachers observe any sim features that cause difficulty for their students (e.g. problems using controls or interpreting representations) or sim features that seem particularly useful for student learning, or that students particularly liked, please send us a summary of your observations.
3. **Activities or teaching approaches.** We encourage teachers to share their experiences using sims in their classroom. If teachers create activities around a sim or approaches to integrating sims into their classroom, please share these with PhET and our community of teachers by posting to PhET's activity database or emailing PhET.
   Activity database: http://phet.colorado.edu/en/for-teachers
4. **Stories or evidence of effectiveness.** We need to hear from educators who find that PhET is helping their students engage with and learn science. Please share your results with us – anecdotal stories are helpful, and evidence of increases in learning or achievement is tremendous. Email PhET: **phethelp@colorado.edu**.
5. **Donating to PhET:** Help keep PhET free! Individual donations bring science to kids in your school and around the world. Consider $15 to $50+, depending on how much you use PhET throughout the year. It's tax deductible!
   Donate at: http://www.cufund.org/giving-opportunities/fund-description/?id=7397