“Energy Theater”

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Abstract:

Energy Theater a dynamic, full-body activity that engages all students in representing the flow of energy in a range of phenomena. The goal of Energy Theater is for students to use this representation to model real-world energy processes while employing the principle of energy conservation and disambiguating matter and energy. During the activity, students identify the relevant objects in a given scenario, and work together to track the energy through processes of transfer and transformation. This article describes the affordances of Energy Theater in the secondary classroom and provides detailed recommendations about its implementation, tips about possible challenges that may occur and student ideas that might emerge during the activity.

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I. INTRODUCTION

Energy Theater is a dynamic, full-body activity[i,ii] that engages all students in representing the flow of energy in a range of phenomena (see Figure 1). The goal of Energy Theater is for students to model real-world energy processes while employing the principle of energy conservation and disambiguating matter and energy. During the course of the activity, students identify the relevant objects in a given scenario and work together to track the energy through processes of transfer and transformation. The implicit inclusion of conservation of energy in the task structure encourages students to “find the energy” in situations where it appears to be lost or becomes imperceptible.

Figure 1: In this Energy Theater, students represent the energy involved in an apple falling from a tree.

II. ENERGY THEATER: A LEARNING ACTIVITY FOR ENERGY CONSERVATION AND TRACKING

Developed by Seattle Pacific University’s Energy Project, Energy Theater emphasizes energy conservation by treating energy as concrete units that neither appear nor disappear during any process.[iii] While energy can be understood through various representations – including bar charts, pie charts, and Sankey diagrams – Energy Theater particularly supports several core ideas: energy is conserved, is localized, is located in objects, can change form, is transferred among objects, and can accumulate in objects.[iv] As a result, Energy Theater helps students develop a more robust model of energy as a non-material, conserved quantity that can take on a variety of forms. Secondary students can use this model to identify the types of energy present and track energy transformations in conservation problems.

A. Energy Theater in Action

Energy Theater is an activity best suited for groups of 7-9 students. It is designed with specific rules that require conservation of energy. When introducing Energy Theater, it is advisable to make sure the rules are strictly enforced. As students become more adept doing Energy Theater, those rules may be challenged. We suggest the rules remain visually accessible to students during the activity.

ENERGY THEATER RULES[iii]:

- Each person is a unit of energy in the scenario.
- Regions on the floor correspond to objects in the physical scenario.
- Each person is one form of energy at a time.
- Each person indicates his/her form of energy in some way (usually with a hand sign or a specific movement).
- People move from one region to another as energy is transferred, and change sign as the energy changes form.
- The number of people in a region or making a particular hand sign corresponds to the quantity of energy in a physical object or of a particular form, respectively.

Energy Theater can be broken up into three stages: A) Choreography, B) Performance, and C) Critique and Individual Reflection. These stages may be implemented differently depending on the classroom context. In a typical implementation, the teacher reviews the rules of Energy Theater, divides students into groups, and presents the scenario that the students will be representing, e.g., "Describe the energy involved when a person pushes a box across the floor at a constant speed." In the Choreography stage, students discuss and plan to perform an energy scenario. Some groups begin by discussing the objects involved in the scenario, and then place ropes on the ground in large (usually circular) shapes to represent each object (students standing inside a rope circle correspond to energy contained in that object). Other groups discuss what forms of energy are present in the scenario (e.g., chemical potential, thermal, kinetic, etc.). When students reach a consensus on the forms of energy, they pick appropriate hand signals for each form (e.g., students in Figure 2 are using their bodies to make the shape of a K for kinetic energy). Students must also decide what form of energy each group member portrays at the beginning, how each of them will move among object-areas, and how their hand signals change throughout the scenario.

Figure 2: Students participating in the Energy Theater of a ball bouncing.

During the Choreography phase, the instructor circulates the room, making sure that the rules are being followed (e.g., making sure students portray units of energy with their bodies, rather than objects) and listening to students' discussions, alert for interesting ideas. As much as possible the teacher redirects students' questions back to the group. She asks them to think about the physical evidence that justifies the inclusion of a particular form of energy or the transfer of energy to a new object. Groups are encouraged to rehearse once or twice before performing. Students present their Energy Theater to the class during the Performance stage. In an Energy Theater performance that we observed recently, a group of seven students created a representation of a hand pushing a box across the floor at constant speed.

> *Six students stand in one cordoned off region of the floor labeled "hand." Five of them hold their hands in a "C" shape to show that they are units of chemical potential energy, one jogs in place to show she is kinetic energy. In another region of the floor labeled "box," a student is jogging in place representing kinetic energy. Coordinating with one another so that their activities are synchronized, one of the five "C" students starts running in place; the jogging student in the hand runs over to the box continuing to jog. The jogging student in the box steps from the box to the surrounding environment and begins fanning his face, indicating that he is now thermal energy. This sequence continues, with the students representing chemical potential energy gradually becoming thermal energy in the environment through a series of transfers and transformations of energy.*

Following the performances of each group, students have an opportunity for critique and individual reflection. Several strategies for critique and reflection are outlined in Section III below.

B. Learning Goals and the Next Generation Science Standards (NGSS)

Two major learning goals for students participating in Energy Theater are:

(1) Learners should be able to conserve energy locally in space and time as they track the transfers and transformations of energy within, into, or out of systems of interest in complex processes.

(2) Learners should be able to theorize mechanisms for energy transfers and transformations.

An enormous benefit of Energy Theater is that it encourages students to make their thinking about energy visible, which helps teachers identify their students' ideas and build upon them to increase understanding. As learners develop the skills to conserve and track energy through a process, they can also begin to identify the mechanisms behind the individual transfers and transformations. For example, the transfer of kinetic energy of a baseball bat to the ball is related to a force pair between those two objects.

These two goals are aligned with the NGSS Disciplinary Core Ideas about energy (PS3.A or PS3.B) and the Science and Engineering Practice of Developing and Using Models. While the focus of this paper is on implementation of Energy Theater at the secondary level, we believe it can provide students of all ages with an opportunity to reinforce their understanding of several "Crosscutting Concepts" in the NGSS: specifically, Patterns (the relationship between macroscopic patterns and microscopic structure), Cause and Effect, Stability and Change, and of course, Energy and Matter (flow, cycles, and conservation).

C. Necessary Prior Knowledge

Energy Theater can model almost any physical situation across multiple science disciplines (e.g., roller coasters, electric circuits, phase changes, combustion engines, photosynthesis). However, it does require knowledge about a few features of energy. It is helpful for students to know that there are different forms of energy. If students are not familiar with all of the basic forms, they can invent forms they need (e.g., motion energy, electric energy). Prior to Energy Theater, it is preferable for students to recognize that energy can be transferred from one object to another and transformed from one form to another. Whether or not students have heard of the conservation of energy, the rules of Energy Theater enforce that principle implicitly.

III. CLASSROOM LOGISTICS

When introducing Energy Theater, it is helpful to begin by frontloading information about the overall process. Students should be informed about the three stages of Energy Theater so they know in advance that the purpose of this activity is not to find the correct answer (because there are many) but instead to justify the choices they make. They should know that to engage in rich, deep conversations about energy and to be creative in this activity is to succeed. Having a small group of students demonstrate Energy Theater for a simple scenario in front of the class will speed up student understanding of the rules and provide an opportunity for modeling the type of conversation that is expected during Choreography.

A. Choreography

Spatial Constraints

Figure 3: Students participate in the Energy Theater of sunlight hitting a solar bag (a large black bag that rises in the sun).

Energy Theater works best in groups of 7-9 students. Groups with fewer than seven members will have a difficult time representing all the different forms of energy present in most scenarios. Engagement of all students becomes difficult when groups have more than nine students. However, even with 7-9 students in a group, it is still challenging for students to engage in the process of consensus building, in what will quickly become a noisy, motion-filled classroom. If possible, we recommend spreading groups out by sending some to a nearby, quieter space. Students in Figure 3 are using an unoccupied classroom to rehearse.

Time Management

Some student groups won't finish preparing their Energy Theater in the given time. A benefit to the open-ended nature of the activity is that rich conversations result in more nuanced understandings of a given scenario. However, when students enter into negotiations about complex topics, it can leave them without enough time to develop a coherent performance. Often discussions during the planning stage of Energy Theater will focus on a particular detail of the scenario. For example, in one of Wells' physics classes, a group of seniors had a lively discussion about the difference between light and heat, but ran out of time to make sure everyone knew their "part" to play in the theater. If time constraints are an issue, a protocol can be used to keep students from spending too much time on one aspect of the planning process.[v]

Some student groups may finish earlier than others. When this happens, it is usually because their analysis of the scenario is not as rigorous as it could be. If the group has come to consensus about their representation, more in-depth thinking can be prompted in several ways. Teachers can ask students about the scenario on a microscopic level if they have only considered macroscopic energy transfers. Another way to challenge students is to ask them to identify evidence that supports each of the energy transfers they've represented in their theater. Additionally, asking students to discuss where the energy comes from prior to the scenario's beginning or where it goes afterwards can extend their thinking. We do not recommend assigning another scenario for students to work on because it can cause confusion during the performance and debrief.

Student Engagement

It is crucial to hold all students accountable for listening to their peers, and actively participating in knowledge construction during Energy Theater. Students should know ahead of time that they will be responsible for individually demonstrating their knowledge after the activity, but even then it can be difficult for students to engage in consensus building in such a large group. One way to help students work together more efficiently and effectively is to assign roles (such as time-keeper or narrator) that allow them to self-regulate. Having roles also reinforces the norm that every student's contribution is both valuable and necessary for the group's progress.

B. Performance

Each Energy Theater performance is complex and almost always unique because of the students' choice of forms, objects and movements through the scenario. This makes it difficult for the audience to follow without help. Prior to the performance, it is essential for the presenting group to tell the audience about the forms of energy and objects they have chosen. We recommend that students narrate their performance. It may be helpful for groups to perform their Energy Theater more than once, so that the rest of the class can identify differences between performances.

C. Critique and Individual Reflection

Compare and contrast performances

When debriefing with the class after their Energy Theater performance, it is important to stress that this is not the end of the learning experience – it is just one step in the process of refining their ideas. Directly after the performances, we recommend that instructors facilitate a discussion of 1) similarities and differences between groups' performances and 2) supporting "evidence" (facts that are already known about the scenario) and whether students' models are consistent with this evidence. It may be useful to prime students with these critique questions during the choreography phase.

Reflect and Assess

If the instructor wants students to continue reflecting on and refining their models, it is essential for students to preserve their ideas after the performances. There are a variety of ways for students to create permanent representations of Energy Theater (for example, Energy Cubes and Energy Tracking Diagrams, which are described in more detail on a website[v] provided by the Energy Project). At the next opportunity, students can share and compare their recorded representations in pairs or small groups. The goal for students is to critically examine their thinking about energy (in general, and specific to the scenario) and revise it to be consistent with other scientific knowledge. You may want to let students know that this process will produce multiple "correct" answers!

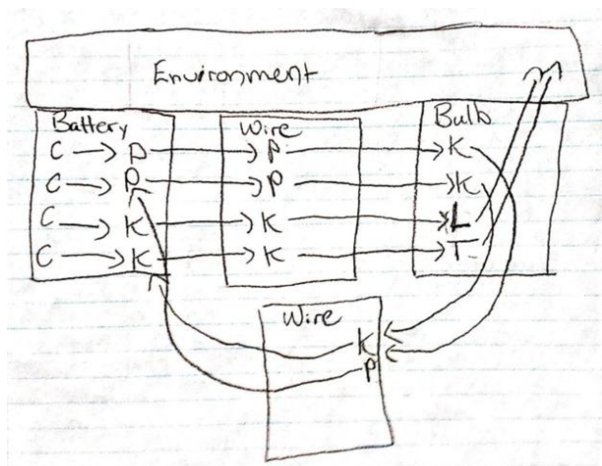

Figure 4: Sample student work from a senior physics class Energy Theater about Electric Circuits. C, P, K, L, and T stand for Chemical, Potential, Kinetic, Light, and Thermal energy respectively.

Aside from the ongoing formative assessment, other possibilities exist for assessing student understanding and providing feedback. After Energy Theater, students could create poster-sized drawings of their Energy Theater in small groups and present the representations to the class. They could also individually design and draw representations of their Energy Theater performance (for example, see Figure 4). Another possibility is for students to write a description of the energy process and record any remaining questions.

IV. COMMON STUDENT IDEAS

A distinct advantage of Energy Theater is that teachers have the opportunity to discover students' ideas about energy during all stages of the activity. Table 1 shows a few common student ideas, the manifestations of those ideas during Energy Theater, and suggestions for ways that teachers can help students make sense of their ideas in relation to physical evidence and desired understandings about energy.

V. CONCLUSION

Like a free body diagram or a ray diagram, Energy Theater is a powerful tool that students can use to track an intangible quantity through a complex scenario. As an embodied learning activity, Energy Theater not only promotes robust discussions about the nature of energy, but also allows students to exercise creativity, and, importantly, have fun. The open-ended nature of this activity encourages students to think more like real scientists; to compare their mental models of the world to physical evidence and established facts. Rather than seeking a pre-determined "correct" answer, students continually refine their models as new evidence and ideas are added. Throughout this process, teachers have a clear window into student thinking, which allows for appropriately targeted feedback. When you implement this activity, we would love to hear about your experience. Additional information about these activities can be found at http://www.energyprojectresources.org/.

ACKNOWLEDGEMENTS

We are grateful to all of the members of the Energy Project at Seattle Pacific University for their collaboration on this work. We especially appreciate Lane Seeley for his substantive work on the website and Amy D. Robertson and Leslie Atkins for her helpful feedback. We would also like to thank the Knowles Science Teaching Foundation for support in the development of this work and teachers in the

Seattle Public Schools for allowing the first author to observe their classrooms. This work was supported in part by the National Science Foundation (DRL 0822342).

Table I: Student ideas, their manifestation in Energy Theater, and possible teacher actions in response to those ideas.

Common Student Ideas	Manifestations of Student Ideas in Energy Theater	Possible Teacher Actions
Students may: - not distinguish between matter and energy.[ii] - think of energy as a consumable substance (i.e. food, fuel).[vi] Younger students often think everything that exists is matter, including heat, light, and electricity.[vii]	Students sometimes: - act as the object instead of chunks of energy, (e.g., if a ball is moving, they will move across the ground as the ball). In this case, students sometimes have the rope-areas act as forms instead of objects. - represent microscopic objects (e.g., electrons) as energy or vice versa.	Teachers can ask students to articulate what they represent and how it differs from what is represented by the locations on the floor.
Students may think: - energy is not measurable or quantifiable.[viii] - energy can be used up or lost to the environment.[ix]	Students may show: - chunks of energy increasing (or decreasing) by students standing taller, shrinking down low, moving faster or slower, or leaving the locations on the floor. - no energy remains at the end of a process by lying on the floor.	Teachers can: - remind students about the rule that people are chunks of energy, which can't be created or destroyed. - prompt students to search for evidence that energy may have been transformed or transferred in order to explain an apparent "loss" of energy.
Students may not consider the appropriate system and environment which may lead them to question conservation of energy.[x]	Students may: - choose to include objects not relevant to the energy processes. - not agree on where the beginning and ending of the scenario should be (how far to take each transfer process).	Teachers can: - help students by clarifying the boundaries of the scenario. - require students to justify their reasoning for including (or not including) particular objects, but remind the class that multiple interpretations may be correct.

[i] Dynamic, full-body activities are also called "embodied learning activities." These are activities in which human bodies, or parts of the body, stand in symbolically for physics entities (Scherr et al., 2013).

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[v] See http://www.energyprojectresources.org/ for a possible protocol and other permanent representations.

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