"Energy Theater": Using The Body Symbolically To Understand Energy

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Abstract. In what we call "embodied learning activities," instructors deliberately arrange for human bodies, or parts of the body, to stand in for entities in the description or explanation of a phenomenon. Embodied learning activities (ELAs) are intended to promote and externalize conceptual understanding in physics, for the benefit of the learner, the instructor, and the researcher. We describe an example of an embodied learning activity called "Energy Theater," in which each participant identifies as a unit of energy that has one and only one form. Objects in the scenario correspond to regions on the floor, and as energy moves and changes form in the scenario, participants move to different locations on the floor. This representation models energy as a substance-like quantity, a model that promotes concepts of conservation, storage, transfer, and flow. The activity becomes a richly featured disciplined symbolic workspace, supporting future studies for both description and analysis.

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INTRODUCTION

Our work originates in the claim that embodied learning activities can help us both to understand physical theories and to externalize our cognition about physical theories, making that cognition more available to other learners and to ourselves. By "embodied learning activities" (ELAs), we mean activities in which human bodies, or parts of the body, stand in for entities in the description or explanation of a phenomenon. In one example of impromptu embodied thinking, a student considering a ball thrown along a parabolic trajectory is considering whether the velocity is zero at the top: she spontaneously makes a "half-parabola" gesture [1] as she says, "Wouldn't it just fall straight down then if it was like, Wup! Pssh." With her hand standing in for the ball, moving her hand along the nonphysical trajectory helps her conclude that the velocity cannot be zero at the top. In what follows, we offer an example of a general framework ("Energy Theater") for generating any number of specific ELAs about energy: that is, planned instructional activities in which we deliberately arrange for human bodies to symbolize units of energy as they move from place to place and change form. The purpose of this paper is to describe the framework and its promise perhaps for conceptual learning in physics, but more certainly for detailed *in situ* study of the learning of physics. Thus, this paper will not attempt to demonstrate the effectiveness of instruction or describe examples of effective cognition, but rather will lay the groundwork for many instances of such further investigation.

THEORETICAL PERSPECTIVE

Deliberate embodiment as a strategy for instruction and for facilitating research on learning is supported by research on motor action in learning and by theories suggesting the significance of embodied metaphor, perspective-taking, the status of representations, and by the methods of interaction analysis.

Motor action in learning

The use of spatial representations in learning, even when representing information that is not originally spatial, improves memory and understanding [2]. Furthermore, relevant motor action improves our ability to imagine spatial transformations [2]. Body motions have also been shown [3] to be helpful in performing non-motor tasks, and may be helpful for laying the foundation for new understanding. Describing what happens to the energy in a physical process is not essentially a motor task, nor is it

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necessarily spatial; however, an embodied approach to the learning of energy may provide the greatest opportunity for understanding, if only because of the general role of motor action in thinking.

Embodied metaphor

The premise of an embodied-cognition theoretical perspective is that we understand the kinds of things that may exist in the world (ontology) in terms of sensory-motor experiences such as object permanence and movement, and that we express this understanding linguistically, through metaphor [4]. For example, we say that a holiday is "on its way," as though it were an object traveling through space towards our location. Human use of embodied metaphor is natural, unconscious, and pervasive, especially in our dealings with abstractions (like time or causation) about which it is not possible to speak literally. Instructional designers may be able to take advantage of this unconscious process by engineering bodily experiences that promote appropriate metaphors.

Perspective-Taking

Mentally taking on the role of an entity in a physics phenomenon appears to be particularly helpful for figuring out physical theories [5]. Experts appear to engage in this perspective-taking naturally and unconsciously, especially at times when the experts are cooperating in solving an abstract problem and are oriented to a communally available graphic workspace (like a diagram drawn on a whiteboard) [5]. With novice learners who do not engage in perspective-taking automatically, we suggest that explicitly directing them to take on the role of an entity they are studying can help them to engage with the entity in a more expert-like manner and thus to understand it better. This explicit perspective-taking also serves to reveal the learner's developing ontology, making it available for examination, negotiation, and refinement.

Appropriate status of representations

Every representation is limited, yet we tend to treat representations as if they were the things they represent [4]. (For example, it is likely that one reason people persist in entertaining the possibility of time travel is that space, through which we *can* travel, is used to represent time.) This tendency can obscure our ability to see both the limitations of the representation and the underlying features of the target concept. Physics students sometimes mistake algebraic representations for physical experiences to which they may refer; for example, students may think of a net force as being exclusively the product of the mass and the acceleration, neglecting that it can also correspond to a sensory experience.

In ELAs, we deliberately arrange for people to use their own bodies to represent physics entities. Among the representational advantages of this approach is that it reduces the likelihood of participants mistaking the representation for the reality, firstly because people identify so strongly with their bodies, secondly because it is obvious that bodies have many features that do not signify anything in the physics scenario being represented (*e.g.,* the color of our clothes and many details about the way we hold ourselves), and thirdly because we recognize our bodies' ability to stand for a vast variety of things, to none of which our bodies are identical. Informally, we observe that using one's own body as a representation tends to lead to more improvisation and creativity, which may make it easier to understand the limitations of any representation.

ELAs in Interaction Analysis

Learning physics involves interaction between the learner and some abstract objects of cognition (among other interactions). Embodied learning activities attempt to externalize the interaction between the learner and the invisible objects of cognition, through encouraging the construction of symbolic objects (that represent ideas) and fields, in which the interaction of ideas is played out in physical form. The research tradition of interaction analysis [6] offers a suite of tools for analyzing interactions between and among persons and their environment. However, since interaction analysis is predicated on *observation* of interaction, the interactions must be rendered observable before they can be analyzed. We believe that by symbolizing the abstract with the concrete, ELAs enable a new depth of the study of cognition.

CONTEXT FOR DEVELOPMENT

The Energy Project is a multi-year project at Seattle Pacific University that studies how people teach and learn about energy. Embodied learning activities play an increasingly important role in the instruction that we design and study.

A FRAMEWORK FOR EMBODIED LEARNING ACTIVITIES: ENERGY THEATER

Energy Theater is a framework that can be used to generate innumerable specific ELAs, each

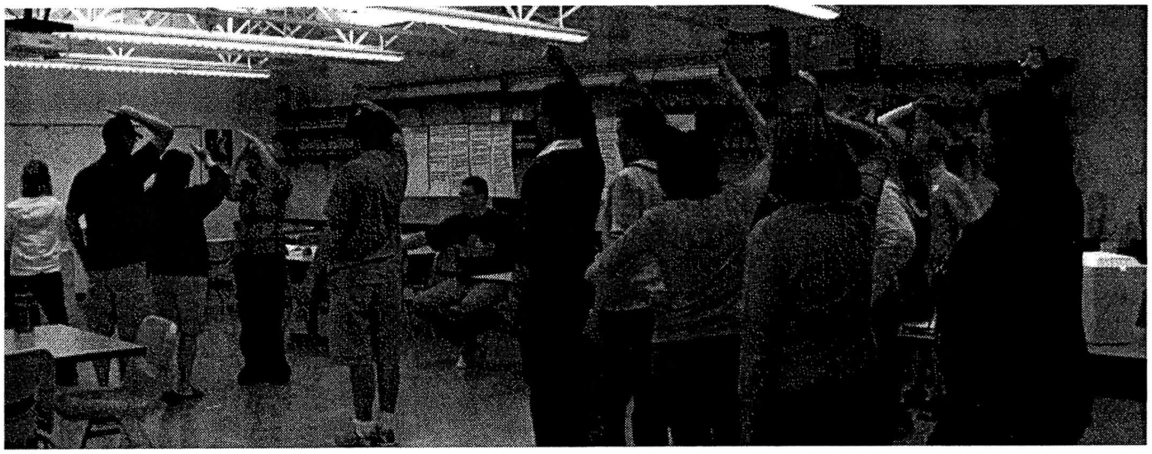

FIGURE 1. "Energy Theater" representation of a hand pushing a box across a floor at constant speed.

corresponding to a different physical scenario. We provide one example scenario and discuss the general rules for Energy Theater.

Example Scenario

We invited secondary teachers in a summer professional development course at Seattle Pacific University to show what is happening with the energy as a hand pushes a box across a floor at constant speed. In earlier exercises, teachers had concluded that energy flows from the hand to the box and from the box to the floor and the surrounding air; that there is a constant amount of kinetic energy in the box, which moves at constant speed; that there is a decreasing amount of chemical energy in the hand (or some other part of the body), which grows tired; and that there is increasing thermal energy in the box, the air, and the floor, which all get warmer.

Rules of Energy Theater

In Energy Theater, each participant is a unit of energy that has one and only one form. Objects in the scenario correspond to regions on the floor. As energy moves and changes form in the scenario, participants move to different locations on the floor. Figure 1 shows a group of participants engaged in Energy Theater. Each of these rules is discussed below with reference to this particular group of participants.

Each Participant Is A Unit of Energy

The participants in Figure 1 have each assumed the identity of a chunk of energy (with the exception of the seated participant in the center, who is overseeing the action). The rule that each participant is a chunk of energy (of equal magnitude) is vital to Energy Theater. To have each participant identify as a chunk of energy is to model energy as a substance-like quantity, a powerful model that promotes concepts of conservation, storage, transfer, and flow [7].

A consequence of this rule in interactions among learners is that an embodied description of the energy is possible only through coordinated action by a group; one person alone cannot show a gradual transformation or transfer of energy. This coordination orients much of the group dialogue toward the negotiation of a consensus. This negotiation is most often conceptually, rather than choreographically, oriented. Thus, one effect of the "unit" rule is a high fraction of conceptual talk during the activity.

Each Unit of Energy Has One And Only One Form

The limitation that each unit of energy has one and only one form helps participants not to "split" energy units into sub-units mid-scenario (which can complicate issues of energy conservation). The means by which participants indicate the form of each unit of energy is determined by the participants, allowing an opportunity for public construction of symbols. The participants in Figure 1 elected to indicate form with hand signs held overhead for maximum visibility. "C" (chemical energy), "K" (kinetic energy), and "T" (thermal energy) were signed with hand-shapes. Advantages of this particular system include flexibility, visibility, and convenience. Disadvantages include the difficulty of telling the signs apart at a glance, especially when many are viewed together. Other participants have used other sign systems with different advantages and disadvantages, *e.g.,* iconic gestures, paper signs with large letters, or colored cards hung from string as a necklace.

Objects In The Scenario Correspond To Regions On The Floor

In Figure 1, participants have designated areas on the floor as corresponding to the hand (where the group of people on the right is standing), the box (on the left), and the air and floor (to the far left, out of the camera frame). One participant, a male wearing shorts in Figure 1, is on his way from the hand to the box. It is helpful if participants designate areas on the floor with large loops of thin, brightly colored rope.

As Energy Moves And Changes Form, Participants Move To Different Regions On The Floor And Change Their Form

Participants play through the scenario as a means of thinking through how their model of energy applies to the situation. In Energy Theater, participants' understanding of energy is actively constructed through the simultaneous use of a range of representational resources [8], potentially including words, gestures, symbolic objects, participants moving their bodies in concert, and other communicative modes. The dynamic, coordinated, multi-dimensional nature of this activity means that there are frequent prompts for individual decision-making: participants constantly ask themselves, "What form am I? Should I go somewhere, or stay where I am? If I go, when should I go?" The activity becomes a richly featured disciplined symbolic workspace comparable to a free-body diagram, useful for both description and analysis both of the physics, by the learner, and of cognition, by the researcher.

CONCEPTUAL ADVANTAGES OF ENERGY THEATER

Energy Theater promotes a conceptual understanding of energy that includes the following features: (i) Energy is conserved. (ii) Energy is emplaced, *i.e.,* it is located somewhere, rather than being entirely nebulous. (iii) Energy is located in objects, which are metaphorically represented as "containers" for energy. (iv) Energy flows among objects. (v) Energy can accumulate in objects. (vi) Energy can change form. While other representations of energy (and its transfers and transformations) may have other advantages, many of them do not support the above conceptual features.

BENEFITS OF EMBODIED LEARNING ACTIVITIES

ELAs offer a unique combination of benefits. They hold promise for promoting conceptual understanding in physics by taking advantage of motor action in learning, embodied metaphors, perspective-taking, and the appropriate status of representations. Furthermore, by promoting the concrete symbolization of abstract ideas and thinking, cognition may be more externalized and thus more available for systematic study, especially through the use of video-based interaction analysis. ELAs are naturally life-sized, promoting large-group involvement. Finally, as a free multimedia technology, the human body is unsurpassed; it is representationally flexible, naturally dynamic, conveniently available, and comes with an extensive suite of tools for symbolization (including gestures, vocalizations, orientations, grips, and so on).

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