Education metaphors we live by

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Metaphor is a means by which we use our literal physical and social experiences (such as containers and conflicts) to understand other, more abstract experiences (such as knowledge and teaching). Metaphors may shape our perceptions and our behavior without our necessarily noticing them, becoming “metaphors we live by” [1]. Influential papers in physics education research use metaphors that have likely shaped thinking in physics education research. Examples of such metaphors include learning is movement, teaching is a battle, a class is an amplifier, the mind is a computer, and the mind is a factory.

I. INTRODUCTION

The theory of embodied cognition posits that all abstractions are understood in terms of basic sensory-motor and social experiences, such as locations, possessions, and conflicts [1]. These conceptualizations are revealed in linguistic metaphors: for example, we might say that we are “halfway through” the year, as though time had spatial extent and we were moving relative to it. Human use of embodied metaphors is natural, unconscious, and pervades our talk. For example, to say someone is “in trouble” or “close to graduation” conceptualizes these states as being locations, and to say that someone “got an idea” or “took a nap” poses these attributes as being possessions. [1].

The nature of the mind, of ideas, and of teaching is not typically an explicit topic of physics education research. Nonetheless, the physics education research literature speaks of these concepts in metaphorical terms. Metaphors may shape our perceptions and behavior without our necessarily noticing them, becoming “metaphors we live by” [1]. In what follows, we identify the educational metaphors in several influential papers. These metaphors have likely shaped thinking and action in physics education research. For example, a conflict metaphor may be especially effective for mobilizing action.

These metaphors were identified as part of a graduate seminar in physics education research taught by the authors. The learning goals of this seminar were for participants to understand the distinctive intellectual history of physics education research; identify the theoretical and experimental foundations of physics education research articles; place influential physics education researchers in the landscape of the field; recognize that physics education research is a discourse, rather than a fixed body of knowledge; and locate their own research in the larger discourse of physics education research. Course materials are available at compadre.org/books/10ERinPER.

II. EXAMPLES OF EDUCATION METAPHORS

Below we identify six distinct metaphors in physics education research: learning is movement, teaching is building, a class is an amplifier, the mind is a computer, and the mind is a factory. This is not an exhaustive list of metaphors in physics education; rather, it is a sample of metaphors present in influential papers, intended to illustrate the variety of conceptualizations of physics teaching and learning in the literature.

We identify metaphors by examining the language authors use to describe physics teaching and learning, including grammatical indicators such as verbs and prepositional phrases as well as an article’s prevailing imagery. Most works use a number of different metaphors. Our selection of a prevailing conceptualization is intended to illustrate a particular metaphor, not necessarily characterize the paper.

A. Learning is movement

A common metaphor for learning is that learning is movement from one place to another. A classic work in physics education literature, Arons’ “Cultivating the capacity for formal reasoning: Objectives and procedures in an introductory physical science course,” makes extensive use of this metaphor [2]. In this work, learning is most frequently described as movement along a path: Students are described as being “led to” understanding or “led through” a sequence of exercises. Good instruction is a “promising channel” directing students to a more desirable place. The author proposes an instructional framework that “impels students toward” formal operational thought and “draws them through” experiences. Some students “struggle toward” clear expression of ideas; others are “somewhat farther along toward” formal reasoning, but still “run into formidable obstacles.” One student is described as having “made a major additional stride toward” understanding. A sudden increase in understanding is described as a “breakthrough.” In a few cases, learning is described as
upward movement: students “attain” the formal operational “level” of intellectual development described by Piaget [3]. (The title of the paper proposes a different metaphor, in which the mind is a container whose volume increases with increased knowledge; but this metaphor appears only rarely in the narrative.)

Another influential work using the learning is movement metaphor is Wenger’s “Communities of Practice: Learning, Meaning, and Identity” [4]. This work, however, conceptualizes learning primarily in terms of inward movement rather than movement along a path: learners move from “legitimate peripheral participation” to “central participation” as their expertise increases.

B. Ideas are concrete objects

The metaphor of ideas as concrete objects is widespread in physics education research. This image is in line with constructivist learning theory, which envisions learning as a process of building complex structures from simpler parts. An influential application of constructivism to science education, Posner et al’s “Accommodation of a scientific conception: Toward a theory of conceptual change” [5], exemplifies this metaphor. In the learning process students “acquire” new concepts, which must “fit into” the existing set and can “displace” old ones. Concepts can be “retained,” “reorganized,” “replaced” or undergo “fundamental revisions.” They can also be “viewed,” “grasped,” and may change under “impact,” emphasizing their concrete nature. There is explicit reference to students constructing representations, which are then “objects” of assessment and “tools” of thought.

Posner and coauthors assert that learning is “a rational activity” in that decisions are governed by principles and rules (presumably in contrast to behavioral conditioning [6], which preceded constructivism historically). Though Posner uses the term “conceptual ecology,” the paper contains few references to any of the features associated with relations of organisms to each other and the physical environment, such as competition among species or food chains.

The metaphor of ideas as concrete objects is also present in papers by Trowbridge and McDermott on student understanding of the concepts of velocity and acceleration [7]). In those papers, students are variously described as “having,” “acquiring,” “grasping,” and “bringing” ideas and concepts, which can “remain intact.” Concepts can form a “repertoire,” and the learning process is “establishing connections” between new and existing concepts. Conceptual understanding can be “present” or “absent,” knowledge is “gained” and conceptual difficulties are “hurdles” to be “overcome.” Trowbridge and Posner share an explicit basis in Piagetian constructivism, which “models the mind in terms of inferred structures” [8].

C. Teaching is overcoming resistance

A metaphor of teaching as a struggle to overcome an opposing force appears in the paper that introduced the FCI: “Force Concept Inventory,” by Hestenes, Wells, and Swackhamer [9]. The authors describe teaching in terms of “overcoming” misconceptions in a process in which these misconceptions are “elicited and treated when they are prone to conflict with the Newtonian concepts.” Some students have a “host” (army) of deficiencies. Certain of the misconceptions are said to be “most difficult and usually the last to be overcome” and unless “dealt with effectively” are likely to “persist.” The misconceptions themselves are also described in terms of conflict: students treat interactions as a “struggle between opposing forces” in which “victory belongs to the stronger” or in which the “more forceful” actor exerts a greater force and “wins out over the other.” Thus conflicts are invoked on at least three levels: between forces, between Newtonian and non-Newtonian concepts, and between a teacher and the commonsense beliefs of her students.

The teaching is overcoming resistance metaphor emphasizes that students’ incorrect physics ideas pose a threat. The authors warn that the failure of conventional physics instruction to overcome incorrect beliefs “could not be more serious”; they offer a “gloomy assessment” and refer to a “sorry state of affairs.” A call-to-arms is provided by the claim that the contents of the article and the tool it introduces “can make a difference!”

D. A class is an amplifier

A pervasive metaphor in physics education research conceptualizes student performance as a signal (such as an electronic signal) that ought to be amplified by instruction. In the class is an amplifier metaphor, the key quantity is the “gain,” which is the amount by which the signal is amplified (typically the ratio of the magnitudes of the output and input signals). The use of the term “gain” to describe improved student performance caused by instruction was pioneered in one of the most frequently cited articles in physics education research, Hake’s “Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses” [10]. The term appears dozens of times in the article, and has been taken up extensively in the physics education research literature [11]. Hake’s gain is intended to represent the fraction of the possible improvement in student performance that results from the application of a particular instructional method: the higher the gain, the greater the course’s effectiveness. A common standardized test is the “detector” of student performance, comparable to a voltmeter or oscilloscope.

Conceptualizing student performance as an electronic signal brings a distinctive physics disciplinary sensibility to education research. The class is an amplifier metaphor prioritizes quantitative analysis along with “scientific
objectivity and detachment” [10]. Though there may be “bias in the detector” (imperfect assessment of student performance through standardized testing), this is be mitigated by careful investigations of “statistical reliability” and “systematic errors” including “false positives.” “Gain” is expressed as a detailed mathematical formula and values are divided into high, medium, and low regions on plots of student performance. “Noise” from systematic errors contributes to the width of these distributions. The conclusion of the study is that “it is extremely unlikely that systematic error plays a significant role in the nearly two-standard-deviation difference observed in the average normalized gains” of traditional and interactive-engagement courses, implying that “this difference primarily reflects variation in the effectiveness of the pedagogy and/or implementation.” Overall, such quantitative analysis conceptualizes a national set of physics classes as a population of broadly similar items.

E. The mind is a computer

Metaphors for intelligence frequently reflect the most advanced technology of the era in which they appear [12], and the metaphor that the mind is a computer has been influential for several decades [13]. A classic physics education article by Redish, “Implications of cognitive studies for teaching physics,” exemplifies this metaphor by characterizing cognition in programming terms [8]. This article states that “we process visual information,” refers to the “analysis of sensory data,” and describes a basic element of a mental models as “a ‘chunk’ or ‘object’ (in the sense of object-oriented programming).” A model is described as “a collection of closely-linked data together with some processes and rules for use”; it consists of “propositions, images, rules of procedure, and statements as to when and how they are to be used.” The article warns that “people may not know how to ‘run’ the procedures present in their mental models.” The account suggests that “an essential component of a mental model is the process for access to information,” and observes that in some cases “a student ‘has’ the information, but it is inert and cannot be used or recalled except in very narrow almost preprogrammed situations.”

This article cautions that “the sharp, crisp operations of formal logic or the digital computer are not appropriate models for the way most people think.” However, the alternative that is proposed—that thinking is “fuzzy”–recalls “fuzzy logic,” an approach to computing based on degrees of truth rather than binary operations. Overall, the conceptualization is in the tradition of artificial intelligence-oriented cognitive science [14].

F. The mind is a factory

In another metaphor that has been influential in physics education research, the construction of ideas is conceptualized in terms of manufacture from raw materials. Smith, diSessa, and Roschelle epitomize this metaphor in “Misconceptions Reconceived: A constructivist analysis of knowledge in transition” [15]. In this paper, learners derive advanced knowledge from prior understandings that have a small “grain size.” These grains are described as “resources” (raw materials) for cognitive “growth” (perhaps analogous to economic growth). In this conceptualization, learners have many such resources, and the resources are valuable to the extent that they are “productive” (i.e., lead to sophisticated reasoning). The quality of an idea is evaluated not in terms of its correctness but in terms of its “richness” and “generativity.” The production of a sophisticated concept from “knowledge in pieces” is a process of “refinement,” in which the undesirable parts of an idea are separated out from those that are “useful” and “functional.” This manufacturing metaphor is intended to convey continuity between novices and experts: novices can transform into experts the way wheat can transform into flour.

III. SIGNIFICANCE OF EDUCATIONAL METAPHORS

Our perspectives on learning matter because “what we think about learning influences where we recognize learning, as well as what we do when we decide we must do something about it” [4]. Whether authors consciously choose metaphors to help illustrate their views on teaching and learning, or express tacit underlying assumptions metaphorically, metaphors play an important role in communication and can influence readers.

The influence may be political: for example, predictions of imminent disaster (e.g., “Rising Above the Gathering Storm” [16]) may be used to mobilize communities and influence funding priorities. The metaphor that teaching is a battle serves a similar purpose by conveying a sense of urgency that is perhaps all the more powerful for being implicit. Furthermore, those who heed the “call to arms” gain membership in an exclusive group: for example, members of the Modeling Instruction community [17] (not coincidentally associated with Hestenes) identify themselves at conferences with ribbons attached to their badges.

For another example, it is likely that the metaphor of ideas as concrete objects that may be acquired, reorganized, built, etc., has influenced both the research and teaching communities by, among other things, promoting a view of students’ ideas as stable: researchers rarely challenge the assumption that once a misconception has been effectively treated it remains in the new condition. The learning is building metaphor also promotes the view of experts as individuals who have more, and better organized, possessions than novices. Metaphors of manufacturing and/or consuming goods may be particularly ingrained in western societies and may play a powerful, unseen role in
ensuring the dominance of certain theoretical perspectives on learning and teaching.

The growing size and diversity of interests in the physics education research community is a challenge for communication. Attending to metaphors can help by providing both authors and readers with additional tools for presenting and interpreting each others’ work.

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