What's a Situation in Situated Cognition? – A Constructionist Critique of Authentic Inquiry

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Abstract: Four papers by learning scientists engaged either in design research or cognitive-developmental studies consider concreteness, context, content, pedagogy, and situativity and their implications for design that fosters opportunities for students to learn subject matter through experiencing authentic scientific/mathematical inquiry. The authors furnish both theoretical considerations and recent classroom- and laboratory-based empirical findings to question prior interpretations of students' capacity to model and abstract from situations, to generate examples, to transfer, and to make insightful connections. The papers jointly suggest that even simple objects may nevertheless undergird *emergent situativity* that provides sufficient context to which learners can bring diverse personal resources. Model-based design may be as intellectually honest, culturally respectful, cognitively generative, and scientifically/mathematically authentic as learning that draws more directly on students' out-of-school resources. The authenticity of 'authentic inquiry' may depend more on engagement and reasoning it enables than on specific content and a priori "good-science" practices it recruits.

Overview of Symposium Panel

Education researchers and psychologists involved in the design and study of student interaction with learning tools have demonstrated the potential roles of modeling—building models, interacting with models—as vehicles of meaningful teaching and learning of subject matter content (Lesh & Doerr, 2003; Verschaffel, Greer, & De Corte, 2000; Wilensky, 1999). At the same time, proponents of 'situated learning' have proposed that student learning is more engaging, meaningful, and democratic when students have opportunities to draw on real-world situations and especially situations they are personally immersed in, such as issues of their community (Freire, 1974; Ladson-Billings, 1995; Lave & Wenger, 1991; Greeno, 1998). It may appear, then, that practices of authentic inquiry would be best fostered through engagement in activities that are both model based and situated in students' real-world activities. Indeed, some designers have interpreted the combined calls for modeling-based and real-world-driven inquiry by creating activities that "go out to the streets" to collect data that is then analyzed both to practice scientific/mathematical skills and, in turn, to facilitate change back in the community. Whereas we recognize the potential of dialogical pedagogy to create richly contextualized learning activities that leverage students' out-of-school situatedness and agency, we submit that intramural situatedness, too, can achieve these goals. That is, a more nuanced interpretation of 'context,' which complexifies relationships between pedagogy and content, may enable designers to appreciate the potential of *emergent situativity* of scientific inquiry. Even Lego bricks or computer-screen pixels, a far cry from what some may call 'rich context,' enfold potential for an engaging, personally meaningful, and authentic exploration into content.

In this symposium, we will: (a) examine prevalent interpretations of the notion that 'situations' should be imported 'as is' from students' extramural activities; (b) suggest that modeling-and-simulation learning environments that include manipulable and/or programmable objects can elicit the necessary situatedness of learning activities; (c) propose that model-based learning activities can be designed to draw from both real-world situations and from "hard-boiled content"—we see modeling as living in the middle (see also Gobert & Buckley, 2000; Lehrer & Schauble, in press; Levy & Wilensky, 2004; Stieff & Wilensky, 2003; Wilensky & Reisman, in press). The epistemic game (Collins & Ferguson, 1993) of building and "running" models enables coordination between the world as we naively know it and the world as scientists and mathematicians know it (see also Schön, 1981).

The authors in this symposium build on empirical data to interpret the constructs 'situation,' 'context,' 'concrete,' and 'authentic' not according to superficial criteria of the materiality or familiarity of media, learning tools, and content, but as indexed by the phenomenology of students who are immersed in model-based learning environments and are recruiting cognitive resources that include personal context, imagination, and pretense skills. diSessa warns that too narrow an interpretation of cultural situatedness may preclude the potential generativity of intuitive, "abstractable," knowledge inherent in cultural practices. Abrahamson argues for the authenticity of mathematics-learning experiences grounded in immersive construction-and-simulation activities—given an interesting problem, liberty to explore, and judicious shepherding, a community of learners can build intellectual edifices from simple blocks. Blikstein and Wilensky present an innovative computer-based learning environment that integrates and juxtaposes within a single medium real-time experimentation in physical and simulated phenomena—this design challenges the dichotomies outdoors—indoors and real—model. Comparing this physics design to Abrahamson's mathematics design demonstrates what source materials each domain requires so as to construct valid models. Uttal, Amaya, and Marulis demonstrate that interaction factors and not materiality per se affect the likelihood that young learners will appropriate objects as representations. All the authors agree that the authenticity of designed inquiry is measured by the conceptual processes and appropriation of procedures that it promotes. From this perspective, any medium, technology, or activity—any context—where students learn content through solving difficult problems, for which staple algorithms are not provided, is authentic.

Abstracts of Panel Participants

Culturally Wide-Spread, Abstract Structures and Their Implications for Learning Mathematics and Science

Andrea A. diSessa

Education is full of exhortations that learning activities must be embedded in the everyday lives and contexts of students in order to be maximally effective. One of the most pointed and important versions of this idea is that the particulars of diverse cultural communities should be exploited as "funds of knowledge" (Moll, Amanti, Neff, & González, 1992) in making "abstract" school mathematics and science sensible to and appreciated by non-white, non-middle class students. So, common activities, such as crafts, art, and pastimes of non-mainstream cultures should be brought into school to motivate, situate, and support learning math and science with *culturally specific competence*.

While supporting the essence of this advice, the contention of this presentation is that conventional interpretations of it unnecessarily narrow the field of consideration for creating "authentic" and "culturally situated" learning activities. There are several moves that open up a much greater range of possibilities. The first is the recognition that cultural activities are deeply generative. Within any culture or community, new "games" and variations of old activities are easily taken on because they share a family resemblance with well-known particular ones. Thus, to be well-connected to a student's heritage, we need only exploit those family resemblances, not literal activity importation. The second move stems from a deeper view of the nature and generativity of cultural and intuitive knowledge. We will make the case that much of this kind of knowledge is—counter to what is probably the mainstream view—highly abstract in nature, and thus not bound in literal reproduction of culturally or individually specific experiences. The possibility of an abstract deep structure in cultural or individual experiences opens up the field of "authentic and situated" activities far beyond stereotyped or quickly recognizeable ones. Even more, "abstract deep structure" suggests the possibility of a much wider reservoir of "funds of knowledge," which are simply NOT culturally specific.

These largely theoretical arguments will be exemplified in a current project called "Patterns of Change and Control." In this project, we seek to understand the intuitive pools of knowledge lying behind children's abilities to comprehend and control many situations in the world—physical, social, and otherwise. The intuitive patterns we believe children know about are things like "balance," "threshold," "stability," "stickiness," "pumping," and so on. In a summer course aimed at eliciting and developing ideas like these, we feel we developed good preliminary evidence that many "naïve" student ideas are, in essence, highly abstract and travel easily across very great divides, such as between physical and social phenomena (diSessa, 2000; diSessa, in press). They are emphatically not "bound" to one or a few recognizable, particular activities. Example data includes the fluid ability of students to generate examples in highly diverse particular settings. Drug addiction, sumo wrestling, and the break-up of a dating pair are all seen easily as examples of one particular pattern (threshold). Furthermore, we see very little reason to expect much difference in these ideas across cultures, although examples students can give and explain likely are more culturally specific. Finally, we believe that certain simple mathematizations (in particular, writing computer programs to model such phenomena) are exceedingly natural and productive (rather than abstract and needing extensive coaching and scaffolding). This last claim, however, probably depends on cultural experiences that may not be as universal as those that support understanding patterns in their own terms.

By the time of ICLS, we will have further classroom data testing the abstract nature of students' knowledge of patterns and their ability to mathematize it, and we will have done at least one controlled, laboratory experiment aimed specifically at illuminating the level of abstractness in students' knowledge of "patterns of change and control."

"Because In the World, There Are More Blocks of This Type": The Real-Worldness of Immersive Combinatorial Analysis as a Grounding of Simulated Probability Experiments

Dor Abrahamson

Underlying any administration of mathematical concepts is a covert dissemination of values, norms, and beliefs pertaining to mathematical practice and learners' critical agency therein (Cobb, Gravemeijer, Yackel, McClain, & Whitenack, 1997). Specifically for mathematical inquiry, I ask, 'Which designs foster opportunities for students both to develop deep understanding of content and to experience effective practices?' My argument is that *the authenticity of 'authentic inquiry' depends more on the types of engagement and reasoning it enables than on the specific content or structures it recruits.* I support the argument with data from an implementation of a modeling-based design for probability.

In discussing school-based situational contexts, I examine pedagogies that apparently motivate the design of the learning environments where mathematical content is situated. However, the objective of this paper is *not* to evaluate pedagogies per se but to comment on designs that purport to implement these pedagogies. That is, mathematical and scientific meaning can emerge successfully both through Freirean design (e.g., Blikstein, 2002) and design for discursive classrooms (e.g., Cobb & Hodge, 2002). Yet whereas choices of pedagogy are more likely to be informed by educators' deep-rooted philosophical and ethical dispositions, by considerations of the resources and needs of target populations, and by political contexts, agendas, and motivations, choices of particular designs could be informed by the extent to which these designs are likely to implement the desired pedagogy. Specifically, I submit that students can potentially engage in deep mathematical discussion of personally-relevant matters even when and *because* students' agency plays out in arenas that are, at least initially, one step removed from "the thing itself"—namely, arenas such as model-based learning environments.

The roles of modeling as supports for deep understanding of mathematical content have been discussed widely (e.g., Lesh & Doerr, 2003; Verschaffel et al., 2000; Wilensky, 1995). A focus on building/interacting with models suggests a shift in the interpretation of 'context.' Extramural situations may initially trigger and frame the mathematical reasoning, yet the model, a medium more amenable for exploration, *gradually* constitutes the locus of active reflection, imagination, and conjecture. The model becomes a rich object onto its own that enables students to embody and pursue coherent structures through generating, examining, discerning, and articulating emergent patterns of relational regularity bearing beyond specific data sets. In sum, initially "neutral" materials are more generative than raw data in terms of: (a) eliciting a diversity of students' personal interpretations; (b) suggesting relations to other mathematical concepts; and (c) enhancing the prospects that students will correctly model situations in future encounters with suitable situational contexts. The modeling materials take on a mathematical life.

To support my position I will discuss findings from implementations of *ProbLab* (Abrahamson & Wilensky, 2002; see Figure 1, below) an experimental model-based unit designed for middle-school students studying probability and statistics. Specifically, I will argue that students who were immersed in collaboratively constructing a complicated combinatorial space of a stochastic device created a locally *real* world of *emergent situativity* that enabled productive processes of authentic mathematical inquiry. These students subsequently leveraged personal insights into the designed contexts so as to *concretize* (Wilensky, 1991) distributions of random outcomes that were generated by computer-based simulations of probability (compare, in Figure 1, the two right-most pictures). These findings suggest that authenticity of mathematical inquiry is indexed not so much by a priori extramural situativity per se as much as by any generative reasoning that the designed materials and activities afford. Also, students' general engagement around very simple tools suggests that any lack off motivation to study mathematics lies not necessarily in the "dullness" of mathematical objects but in activity design and facilitation.

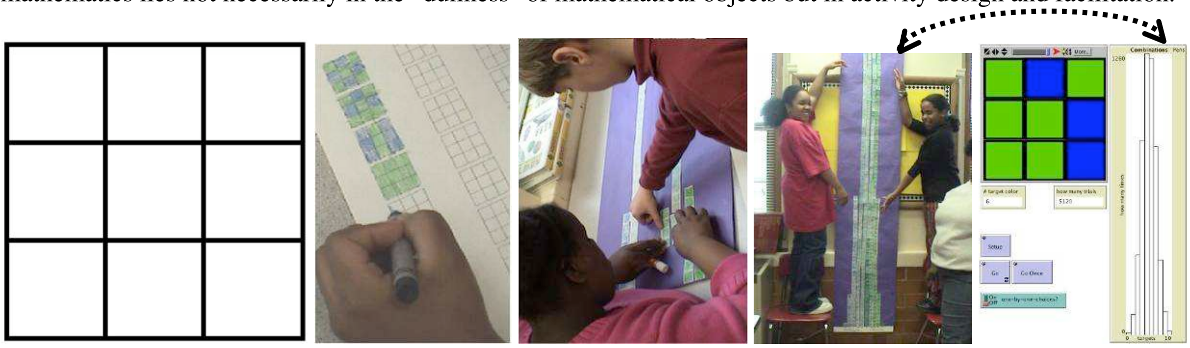

Figure 1. *ProbLab*: collaborative construction of the combinatorial space of the *9-Block*, a 3-by-3 grid, in which cells are either green or blue. Students construct a *combinations tower* and then compare it to simulated experiments.

Implications of this study are that real-world experiences can be created in model-based mathematics learning environments. Thus, modeling-based design could be instrumental in implementing *culturally-relevant pedagogy* (Ladson-Billings, 1995). For example, design for statistics education need not focus primarily on practices of assembling reliable data sets, e.g., through quasi-ethnographic charting of the community, as much as on conceptual processes of making sense of such data through constructing generative models that accommodate the data as a case study. The pragmatics of available resources, e.g., classroom time, may, too, bear on designers' decisions whether students should go out to the streets or whether the streets should be reconstructed in the classroom (see also von Glasersfeld, e.g., 1992).

Linking Real-World Sensing and Multi-Agent-Based Computer Models

Paulo Blikstein and Uri Wilensky

What do we obtain from "going out to the world" as a platform for learning? The multiple aspects of this experience have been explored by different schools of thought in education. John Dewey (1916) was one of the first to emphasize the importance of connecting school learning and real-world experiences. Critical pedagogy argued that departing from the learner's context and previous knowledge is crucial to foster de-facto emancipating and motivating learning (Freire, 1974). Constructionist educators (Papert, 1991) posited that building personally-meaningful public artifacts is central to promote sustainable and deep learner engagement. However, critics of such pedagogies would argue that the world might not afford the necessary information and opportunities for students to learn the 'official' school content: One cannot make sure that acid-base reactions, for instance, are out there situated in the world.

While concurring with claims about the relevance of the learner's context, background, and concrete experiences for education design, we acknowledge that the current tools for scientific exploration available for students limit the kind and complexity of their real-world investigations. Thus, we submit that the disconnect between what one can learn in a fully situated environment and the more traditional school content is due, perhaps, to the lack of appropriate tools to 'dissect' reality to the appropriate level of analysis. Even if, by definition, Physics, Chemistry, and Biology are 'out-there' in the world, most phenomena are invisible to human vision and time scale. Many patterns in nature are too long, too fast, too small, or too large for learners to extract and understand their underlying structures. Canonical examples are weather behavior, chemical reactions, housing and traffic pattern, particle physics, and population ecology. We need, thus, new technological tools which foreground and unveil the deep structures of such phenomena. In this paper, our focus will be *hybrid modeling*, a framework for scientific exploration and modeling which merges two types of educational technologies commonly used (separately) in schools. The first kind is robotics and electronic sensing (Martin, 1996; Resnick & Ocko, 1991), which makes possible a wide range of experimental activities in the real world. The second technology is multi-agent simulation, which enables learners to create models to understand complex social and natural phenomena departing from very simple behaviors embedded into elementary computational agents (Wilensky & Reisman, in press; Wilensky & Resnick, 1999).

This paper describes a research project that, by linking the two technologies, attempts to simultaneously broaden the possibilities of situated investigation and ground computer modeling with real-world validation. For that goal, we are developing software and hardware tools to bridge computer models and sensing in real time (see Figure 2, below). Typically, students build a computer model of a particular phenomenon, such as heat transfer, and a sensor-equipped physical device. These are connected by an analog-to-digital interface. Students are able to run their computer models in tandem with the physical apparatus, comparing the outcomes of both, and debugging their model until it matches the real-world data. We are currently building proof-of-concept systems for 'hybrid' explorations in heat transfer, gas laws, acid-based and oscillating reactions, and Materials Science. Our main goal, however, is to create a technological infrastructure to enable students to build their own systems.

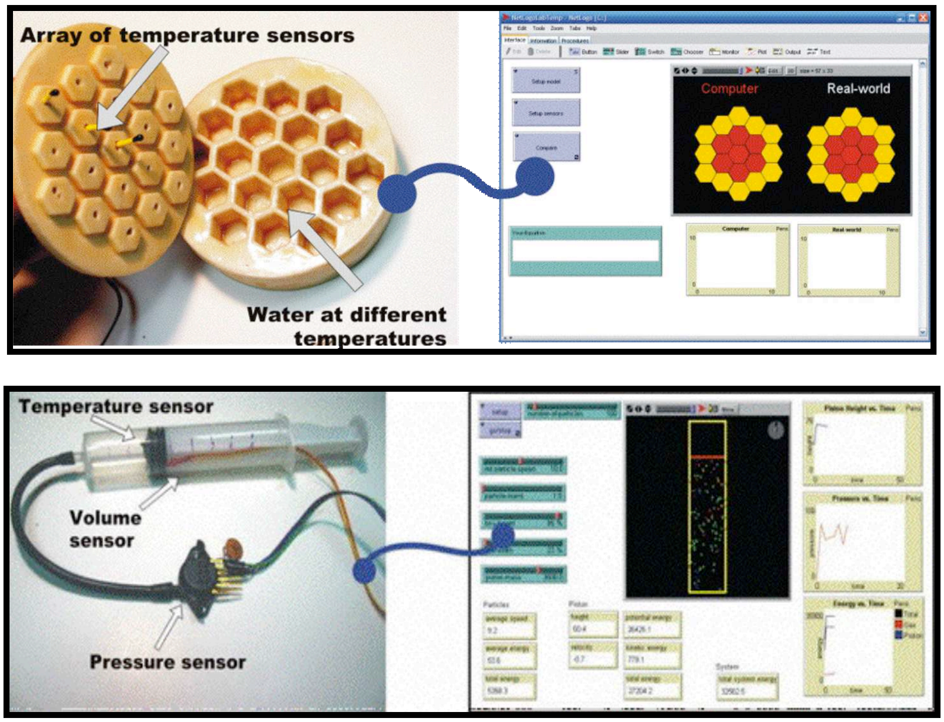

Figure 2. Two 'linked' systems for real-time physical/virtual investigations: heat transfer (above); gas laws (below).

We conducted a case study comparing the artifacts generated by undergraduate and graduate students in two distinct conditions. In the first condition, students created multi-agent-based models *with no* sensors. In the second situation, another group of students built hybrid models *with* sensors. All students built their models as an assignment in an 'Educational Design' class. Based on our analysis of their artifacts and interviews, we are identifying the learning benefits of hybrid, "trans-media," sensor-equipped models as well as determining to what extent this approach can effectively expand the possibilities of situated investigation (see also http://ccl.northwestern.edu/netlogolab).

When, How, and Why Do Concrete Objects Facilitate Young Children's Learning?

David H. Uttal, Meredith M. Amaya, & Loren M. Marulis

The assumption that young children's thinking is inherently concrete is a central tenet of many developmental and educational theories. Scholars such as Montessori (1917; Lillard, 2005) and Piaget (1970) have suggested that young children know the world primarily through physical interactions with it. Their mental representations thus are based on the way in which the information is experienced, rather than on symbolic, abstract representations of concepts. Although many researchers (Gelman, 2003; Simons & Keil, 1995) have challenged this notion, it continues to have great sway (Ball, 1992; Clements, 1997).

The idea that young children's thinking is based on their experiences with the environment has led to the development of concrete educational tools that are designed to be physically manipulated. For example, one can find letter or number magnets stuck to refrigerators in many American homes. In the classroom, teachers can use a variety of more formal systems, such as mathematics manipulatives, that are intended to capitalize on young children's concrete thinking.

Despite the enthusiasm for the use of concrete materials, relatively little controlled research has evaluated their effectiveness. The research that has been conducted has yielded mixed results. Consider, for example, research on the effectiveness of concrete mathematics manipulatives. On the one hand, several studies have demonstrated that the use of concrete manipulatives can facilitate children's understanding of mathematical concepts (Resnick & Omanson, 1987; Martin & Schwartz, 2005). Yet on the other hand, systematic reviews of research on the effectiveness of the use of manipulatives have not found a consistent advantage over other forms of instruction (Sowell, 1989; Uttal, Scudder, & DeLoache, 1997), and research has shown that children consistently fail to transfer what they learn from using manipulatives to written representations (Resnick & Omanson, 1987).

Our research examines the effectiveness of concrete objects in a variety of learning contexts. Our goal is to reveal, through systematic and controlled studies, the conditions under which concrete objects facilitate (or inhibit) learning. We will present the results of two sets of studies. The first focuses on 4-year-olds' learning of the symbolic properties of letters and numbers. We asked the children either to play with concrete (magnetic) letters or numbers or control stimuli (standard toys that involved games similar to those played with the letters or numbers). We then tested the children's use of the letters and numbers to represent quantities or objects. For example, the children were asked to use the magnetic numbers as well as a crayon to represent the number of "cookies" hidden in a container. Likewise, they were asked to use letter magnets and a crayon to represent the identity of a hidden toy animal.

We found that playing with the concrete objects does not facilitate learning. In fact, in some situations, it actually hurt performance. However, using the concrete objects in a symbolic way (to represent quantity or identity) does promote symbolic understanding. For example, using a magnetic letter to represent the identity of an object made it easier for the children to use a crayon to do something similar. These results suggest that concreteness per se may matter less than how or why the objects are used. We will also discuss additional lines of research that focus on the use of concrete manipulatives in the classroom. Taken together, our studies suggest that, as a Learning-Sciences community that frames design principles for learning with understanding, we may wish to reexamine what we mean by 'concrete.' For example, is concreteness an inherent property of learning material or a psychological relationship that the learner develops towards any material (see also Wilensky, 1991)?

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