International Society of the Learning Sciences

Seeing Learning Sciences Research as Modeling

Jeremy Roschelle, Digital Promise, jroschelle@digitalpromise.org

Abstract: Researchers in the Learning Sciences take two prevalent stances: research as building theories or as developing designs. The connection between theories and designs is most often filled in by methods, but an alternative stance is possible: research as improving models. The modeling stance seeks parsimonious, useful, illuminating descriptions of learning activity systems. Models can help us understand and express how variability (in all its forms) plays into, is enacted during, and results from designed learning activities. Building models often requires employing multiple theories, methods, and design elements; a modeling stance recognizes that our research often elaborates a multi-level systems view. An explicit modeling stance may lead to developing descriptions of complex systems, inviting multi-stakeholder teamwork to improve these systems, integrating advances in learning analytics and educational data mining, and adding to ability of learning sciences research to tackle challenges at scale.

Introduction: Beyond theory and design

What do learning scientists do? Often our self-descriptions begin with broad ambitions. The ISLS website announces that we are "dedicated to the interdisciplinary empirical investigation of learning as it exists in real-world settings and to how learning may be facilitated both with and without technology." Learning sciences has is an applied science or in the terms of Pasteur's Quadrant (Stokes, 2011), a pioneering science. As a pioneering science, we aspire to use-oriented, foundational, impactful research. And yet what we report may be constrained by what we can publish. The opening description of the aims of the Journal of the Learning Sciences states:

> JLS provides a multidisciplinary forum for research on education and learning that informs theories of how people learn and the design of learning environments. It publishes research that elucidates processes of learning, and the ways in which technologies, instructional practices, and learning environments can be designed to support learning in different contexts.

Note that the requested types of contribution have theories and designs as the two clear anchor points. In a recent handbook chapter, Kali & Hoadley (in press) provide a diagram (Figure 1) that locates Design-Based Research as an epistemic game that connects theory-oriented and design-oriented work. DBR has been subject to critique, e.g., for missing or idiosyncratic argument structures (Kelly, 2004). Some have also observed that design-based research does not adequately address challenges of scaling up, leading to self-critique within the field (e.g. Wise & Schwarz, 2017). This short paper suggests an alternative conception of our work: research as modeling. Modeling also occurs at a middle level between abstract and concrete and between simple and complex. Unlike design-based research, it places greater accountability on developing a logic model or theory of action that can account for variability throughout a learning activity system. This is common in much work that learning scientists do, but we underemphasize our craft of modeling in what we report in publications.

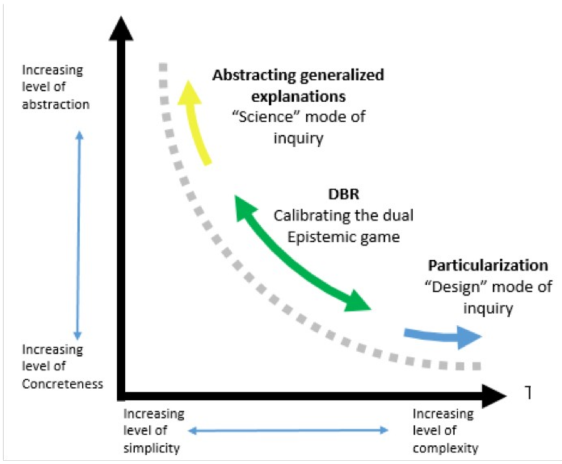

Figure 1: DBR connects science and design modes from Kali & Hoadley (in press), used with permissions

The aim of this paper is to foster discussion at our society's meeting about how to make the practice of *modeling* complex learning environments a priority pursuit for learning scientists. This could entail both a practice of doing modeling to improve theories and designs, but also a pursuit of models as a useful artifact in their own right. Models can help learning scientists to work with others in teams and that can enable scaling from smaller to larger data sets and from exploratory designs to designs ready for messy, real world contexts. This short paper will sketch what a modeling stance might look like in the learning sciences, discusses the potential significance of giving this stance more prominence, and draws out potential implications for individual learning scientists, for collaborations with other disciplines, and for the kinds of research reports our institutions solicit.

Sketching the Learning Sciences as modeling

The Oxford English Dictionary (2021) defines modeling as: “A simplified or idealized description or conception of a particular system, situation, or process, often in mathematical terms, that is put forward as a basis for theoretical or empirical understanding, or for calculations, predictions, etc.; a conceptual or mental representation of something.” Models are useful to scientists because they enable gathering knowledge, forming concepts, clarifying theory, explaining and understanding phenomena, and evaluating truthfulness (Frigg et al, 2020) Modeling, thus, is the art of creating purposefully simple and useful approximations of reality. Credible models organize both knowledge and data to help us reason through a problem without becoming overwhelmed by every factor that could be relevant. Modeling is an iterative process. When we test an approach in expanding contexts, we see additional variation; we realize we need to address it and decide how best to capture and make sense of it. Modeling is purposeful or teleological; we build models to engineer improvement. Modeling is also often collaborative: a shared explanatory structure can make it easier for to integrate multiple perspectives.

What is a modeling stance?

In common with most work in the learning sciences, I suggest that the motivating or driving question for modeling work is to understand how a target population of students learns a complex or challenging subject matter. A tool like Activity Theory invites a modeling stance (see Figure 2, Bury, 2012). The interconnected relationships in the depicted triangles invite a team to look for and map the different interacting elements and processes that together form a learning activity system. In addition, in my experience as a reviewer of research proposals, many projects develop and refine a Theory of Action or a Logic Model, which is a spatial tool for organizing information about all the factors that have a plausible causal relationship to learning. A typical Theory of Action accounts for new inputs to a learning activity system, the training processes and other new resources that prepare teachers to enact it and the learning outcomes that are expected. Many logic models build on Cohen et al (2004). They express a contrast between the new and typical learning activity in terms of what changes among teachers, students and resources in a context. A conjecture map (Sandoval, 2014) can also serve as a logic model. Our field routinely uses models.

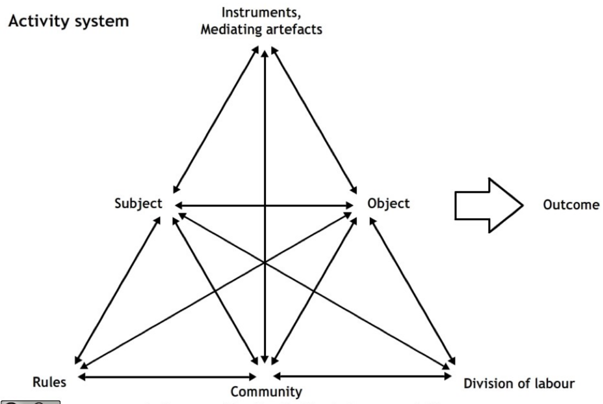

 Figure 2: Activity Theory Diagram

The difference between a modeling stance and design-based research may the object of the activity (always in service of an outcome of better learning).

In **model-oriented research**, a more accurate model of how people learn is the *object* of the research; by having a better model, we can explain and predict all the factors that are important to determining the outcomes. A novel design is positioned as an *instrument or mediating artifact* that enables perturbing the business-as-usual model so we can better understand how learning might better take place

In **design-oriented research,** a novel learning design is the *object* of the research; the design is iteratively improved to incorporate what was learned about relevant factors in the learning process. A good model of these relevant factors is a *mediating artifact* that organizes information so that the design can be improved and/or tested with appropriate control of favors beyond the scope of the design.

To explore why this might make a difference, consider other elements of Figure 2. What happens when our community *rules* and *division of labor* are in service of publishing a design or theory? What happens when investigators (*subjects* in this use of Figure 2) are positioned as designers or theorists? My suggestion when the publishable object is only a theory or a design, much learning science competence is rendered invisible. If the publishable outcome could be a better model of learning in a context—a model that is simple enough to be widely re-usable and complex enough to account for the many factors that contribute to learning—I suggest we will make more visible our rules of good modeling building; we will invite a division of labor where different expertise can contribute to anticipating, explaining and predicting how learning may unfold; we may invite investigators who don't see themselves as theorists or designers, but have valuable contributions to make nonetheless.

An example may help:

> Imagine that a newly available 5G sensor technology allows students in hybrid classrooms (some students are remote, some are together in a classroom) to more smoothly observe the presence of others and shift among different configurations of small groups.

With a theory stance, one researcher sees this as a system which could advance theories of embodied cognition, as the new sensors capture and represent gesture in new ways. With a design stance, another researcher sees opportunities to create new supports for classroom argumentation, based on allowing students to quickly change groups as they share ideas. With a modeling stance, a third researcher sees that in a data set emerging from early field studies, participation in the groups varies quite a bit – perhaps in ways that reflect who is remote and who is in the classroom -- and begins to wonder: in these patterns we see at scale, which kinds of variation should we focusing on? what different theoretical ideas might we need to explain all the variation we see? What kind of structured diagram would allow practitioners, developers and researchers to work together to make sense of what happens when classrooms use this technology? What structure provides the best tradeoff between simplicity and complexity and between particularity and generality? The stance may make an important difference, therefore, in how we frame our a project, what expertise we recruit, and what work gets done.

What are key objectives in modeling work?

As a discussion starter, I suggest some characteristics of model-oriented research below.

The system perspective is elaborated. Researchers taking a modeling stance elaborate a description of what makes up the relevant learning system. This involves *not* taking the designer's word for what the system is nor taking the learning environment for granted, but rather probing the other local resources, capacities, practices, agencies, and other forces that enter in to how the system is enacted and how it is adapted. Improvement Science, for instance, takes as a key practice "seeing the system" with useful but not too much detail (Carnegie, n.d.).

Multiple levels are considered. A modeling stance requires thinking about different levels of granularity and timescales. In one precedent, learning scientists talk about the meso-, midi- and micro-scales of learning activity. For example, Rogoff (2008) talks about cultural, social and personal "planes" of a learning activity. Learning scientists also think across different timescales, conceptualize interventions with different granularity, or developed nested systems of scripts to guide collaborative learning (references omitted to conserve space).

Multiple theoretical and design elements are integrated. In modeling complex learning environments, it is often the case that no one theory provides a comprehensive set of factors and relationships that is suitable for accounting how learning occurs or varies. Likewise, designs that scale incorporate multiple design factors (Roschelle et al, 2021). The modelling work brings heterogenous elements together in a comprehensive view, where theories are elaborated to fit the particulars of designs and implementations.

Logic models support fitting data. In modeling work, a theory of action is not just to organize the processes of evaluating a novel approach to learning, but also a guide to instrumenting all the relationship that need to be measured. As data comes in, we can see if expected relationships are present and strong, or whether the model needs to be modified to better predict and explain the phenomena. New theories or previously uninspected aspects of the design may need to be added to the model to better explain how learning unfolds. The process of fitting data is the key driver of model improvement.

Scaling research enables observing, making sense and adapting to variability. As others have pointed out (e.g. Coburn, , a large *n* is not necessarily the goal of scaling – for example, we should care about the depth of the innovation and shift of ownership (Coburn, 2003). Scale can also be an opportunity to understand and work with learner variability and variable implementations of teaching and learning processes. A modeling stance would collect data at scale not only to expand impact or improve the implementation, but also because we need to study learning at scale to get better at modeling. Gomez et al (in press) make the case, for example, that many issues of diversity, equity and inclusion really only emerge when a suitable scale of data is available.

Each version of the model serves as a parsimonious boundary object. Returning to the idea that the modeling stance involves multidisciplinary teams, success arises when a model is a useful common ground for conversations that bring together different roles and varied expertise. A good model gives each participant's perspective a place, but also enables a team to see the elephant and not just touch their own leg of the elephant.

Rigor is pragmatic and socially-constructed. Classically, rigor is in service of making a strong causal claim and eliminating threats to validity (e.g. in an RCT). Rigor in ethnographic or descriptive research can be about thoroughness and care in accountability to rich data – avoiding misrepresenting or overlooking phenomena. Although a modeling stance may incorporate aspects of rigor from these approaches, my sense is that the quality of modeling derives from contributions to a pragmatic goal of a community. As models are simplifications, methodological perfectionism nor empirically completeness are best criteria for rigor. A rigorous model should help a community pragmatically to organize its progression of inquiries to address a challenge.

Potential implications for the Learning Sciences

The learning sciences describes itself as publishing advances in theory and design. Yet, improving learner outcomes requires a middle ground between abstract and concreteness, as well as between generality and particularity. Design-based research is in the middle, but outputs a design. An alternative stance would produce models of complex learning phenomena. The field could consider how making modeling a priority at three levels:

- **Professional.** If our professional community were to better recognize individual contributions in making and using models, would that clarify what learning scientist do and open up additional career growth possibilities for early and mid-career scholars? Does this open opportunities for learning scientists who are not abstract theorists nor innovative designers, but are still exceptionally good at studying learning in all its glorious variability in complex contexts?
- **Scientific Community.** The International Alliance to Advance Learning in the Digital Era brings ISLS and learning analytic, educational data mining, learning at scale, and other scientific communities closer together. If learning scientists saw improved modeling as a core contribution (alongside advancing theories or designs), might that allow us to work with colleagues in other disciplines who build models? On a smaller scale, when multi-disciplinary teams form, would a focus on building shared models help the teams work better together?
- **Institutional.** Our journals and conferences more easily feature advances in theories, designs and specific research methods then they do contributions to our practices of modeling complex learning environments. We also often aspire to doing more in terms of diversity, equity and inclusion and we aspire to having impact at scale. Would considering modeling as an institutionally recognized form of scholarly contribution help us advance these aspirations?

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