PSLC GAP analysis
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There are many projects that could contribute to the PSLC's focus on robust learning. I see a "Gap analysis" not as a task of suggesting projects to support, but rather as a consideration of three factors (a) the general goals and theoretical framework of the PSLC, (b) the PSLC's portfolio of projects and their overlap with PSLC goals (c) learning issues that are implied by PSLC goals but are not currently being addressed.

Current projects (as of January 2008) are well connected to PSLC at the macro-level and the micro-level. However, because the theories are not fixed but under some degree of development and refinement, locking projects into particular theoretical statements lacks flexibility. It is best not to identify gaps in terms of existing theory but in terms of over-arching PSLC theoretical goals.

The broad PSLC goals are to identify the causes of robust learning—learning that is retained over longer time periods, transfers to new situations, and accelerates new learning. This robust learning goal is served by the LearnLab methodology, because LearnLab contains the classroom environments that are the test beds of robustness. With this perspective, gap analysis is the assessment of how PSLC projects further this goal. My assessment identifies three types of gaps: (1) Assessing robust learning measures and their interrelationships; (2) identifying substantive research initiatives implied by theory; (3) identifying classes of studies which, while not appearing at first glance to be central to PSLC's focus, may lead to enhancing the empirical and theoretical contributions of PSLC research.

1. *Robust Learning Measures.* Most PSLC projects include at least one of three measures of robust learning—long-term retention, transfer, accelerated future learning—as well as, typically, some measure of immediate retention. What the measures of robust learning have in common is their shared distinction from learning measures taken shortly after learning on material that was the object of instruction. However, the measures have some clear differences that warrant some research. In the long run, a theory of robust learning will need to attend to robust learning measurement issues. For example:
   A. What kinds of transfer are implied by what kinds of interventions? When principles or rules govern a domain in math, science or language, will an intervention that affects the principle or rule in one sub-domain be expected to reach to another sub-domain in which a similar rule applies?
   B. Accelerated future learning is not about just any future learning but learning that somehow builds on what was originally learned. Can the conditions on accelerated learning be better specified? In a single study, can it be both conceptually and operationally defined so as to make it distinct from far transfer?
   C. The relationships among measures of robust learning and between these and ordinary post-test learning measures. For example, will learning conditions that support transfer (as measured immediately after learning) also support long-term retention? i.e. does learning strong enough to produce transfer also strengthen the

original learning-retention relationship? Is there a single dimension (i.e., Guttman scalable) ordering of robust learning measures?

These are just a few of many questions about the measures of robust learning and their relationships. These generally are not measurement issues in a narrow sense (e.g. percent correct measures vs. trials to criterion measures), although these are also important. Generally they involve the relations between various measures and some inferred learning that underlies the measurement. They also require clear (operational) measurement definitions. It is important also to make links to the rich literature on learning and transfer. PSLC research adds to this rich literature an emphasis on relatively long time scales and authentic class room learning.

2. *Integrative studies that refine or challenge hypotheses.* The PSLC learning framework accommodates a rich array of studies across domains. The current set of studies samples a large space of learning hypotheses. Hypotheses that are more generative in applying across domains, sub-domains, and clusters may deserve additional attention because of their potential to contribute to general learning principles and learning theory. It is also important to support studies that demonstrate boundary conditions on general hypotheses so as to sharpen their theoretical formulation.
    1. A major theme in the PSLC framework is the assistance dilemma, the choice in instruction between providing and withholding assistance. To establish an empirically validated set of assistance hypotheses, research is needed on the following:y measures of robust learning (see above) when assistance is manipulated.
    2. The learner conditions, e.g. skill level in the learning domain, that affect the outcomes of assistance levels.
    3. The nature of the tradeoffs implied by the general assistance hypothesis. How are different measures affected by different levels of assistance? For example, is the gain from high levels of assistance mainly on simple post-tests? Is transfer a cost for high assistance?
    4. The assistance dimension needs to be scaled for specific instructional studies. For example, is one modality less assistive than two? Are definitions more assistive for vocabulary learning than is learning by context?

B. PSLC clusters have served two functions: (1) as convenient (in respect to numbers and shared interests) working groups (2) as conceptually coherent (through shared hypotheses and theory) scientific themes. Although (1) is a sufficient reason to have clusters, the persistence of a belief in goal (2) suggests some progress to be made in demonstrating scientific coherence within clusters. An alternative is increased demonstration of coherence across projects in different clusters. Either one would support common theory building, but only the former will encourage the PSLC to consider clusters as theory building units. The general need is for studies that will demonstrate or instantiate theory-enhancing hypotheses.
    1. Studies that strengthen cross-project hypotheses at either level—across clusters or within clusters—are needed. These could be new collaborations,

hypotheses applied to new content domains, or studies that clarify theory in some other way.
2. Studies that target fluency beyond knowledge acquisition and refinement, including manipulations involving coordinated inputs and multi-agent communication.
3. Studies that link the mechanisms of multi-agent interactive learning to those of single agent non-interactive learning or studies that identify the unique advantages of multi-agent learning in respect to specific learning domains.
4. Studies that illuminate a principle that governs both parts of the coordinated learning duality, which currently contains both information source modalities and examples/explanations as examples of coordinated input. These two appear to be different in their cognitive foundations.
5. Other theory enhancing studies that do not fit into the above descriptions.

3. *Enhancement Studies.* A third kind of gap exists beyond the central focus of PSLC research, but affects PSLC research conclusions. Studies that could fill this gap have the potential to help explain why robust learning effects sometimes are not obtained and to stimulate additional studies that would produce robust learning.
   A. Studies that address details of classroom and learner activities that influence the effectiveness of interventions. Such studies must have a target intervention but may add a richer set of observations about contexts, including instructor and learner activities beyond the intervention and deeper analyses of student background knowledge and learning habits.
   B. Studies that pursue deeper analysis of learning (probably on fewer learners) and individual learner behavior. Such studies might increase the range of manipulations, observations, and methods (e.g., learner protocols) over what the typical in-vivo study can accomplish. Although some studies may focus exclusively on deeper analysis, an alternative is to encourage studies that include small sub-sample deep studies as part of larger sample more conventional quantitative studies.
   C. Laboratory studies that address PSLC hypotheses outside the in-vivo environment. Although the LearnLab in-vivo studies remain the "gold standard" of PSLC research, the need to carry out strong hypothesis-testing studies that, in principle, could eventually move to in-vivo status is important. Although such studies have always been permitted, their numbers are relatively small because of a perception that they have lower value.
   D. Studies that propose to use existing data shop files to construct models and test hypotheses.