Weaving the Fabric of Adaptive STEM **L**earning **E**nvironments **A**cross **D**omains & **S**ettings (‘Adaptive STEM LEADS’)

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Driving Questions / Purposes

Purposes: *To construct needed new collaborations between the learning sciences, computer science, and assessment communities to design integrative STEM learning environments with robust measures of adaptive learning that address key aspects of deeper learning; make progress in building collaborative science to support STEM integrative learning across disciplines* and settings.*

Driving Questions:

(1) How can environments for integrated STEM learning scale successful efforts across diverse student populations and bridge formal and informal learning?

(2) What innovative research methods, modeling formalisms are needed to embed theoretical models in data-driven computational approaches to capture, characterize & support causal claims about individual & team-based learning, for both traditional and complex, multi-source streaming data?

(3) How can multi-domain threaded learning progressions be created for integrated learning & assessment of STEM subjects?

Convened Participants (20 + 6 Doctoral Students)

Social/Analytics	Comp. Analytics	Assessment	STEM Ed	Bridging Informal+Formal
Kris Gutierrez	James Lester	Jim Pellegrino	Jonathan Osborne	Brigid Barron
Tim O'Shea	Marcelo Worsley	Mark Wilson	Bryan Brown	Nichole Pinkard
Victor Lee	Zach Pardos	Janice Gobert	Shuchi Grover	Tamara Clegg
Patti Schank	Michael Richey	Tony Petrosino		Eileen Scanlon
Roy Pea				

Participating PhD students: Raquel Coelho, Victoria Docherty, Greses Anabell Perez, Rose Pozos, Brandon Reynante, Aditya Viswanath

Invited, unable to attend: Eva Baker, Ryan Baker, Emma Brunskill, Margaret Honey, Ken Koedinger, Marcia Linn, Barbara Means, Katie Headrick Taylor

Process

Pre-conference Prep	Participants contributed key papers on relevant topics to a shared repository. Shared examples from prior envisioning workshops on authoring learning vignettes.
Firehose/Ignite Talks	‘Snapshot of your most forward-looking contribution tackling a primary problem in your work that’s most aligned with this workshop’s goals? Missing elements of your work that would enable it to contribute to a vision of adaptive STEM learning across domains and settings?’ *These enabled us to collectively consider new convergences, prospective collaborations, and high-priority needed developments for advancing this vision.*
Lunchtime	Tech demos and emerging synthesis discussions
Group work on Envisioning LEVs	Group discussions and report out on ideas, design principles in preparation to launch crafting of associated Learning Environment Vignettes (LEVs).
Group Collaborative Writing on Expanded & Refined LEVs	Work in groups to author and report out on design principles and LEVs on three time horizons for targets of needed progress in science and technology ingredient to their further development: State-of-the-Art (Now); 1-3-yrs; 3-5 yrs.

Findings [key findings and syntheses on existing state of the art]

- Examples provided of learning that bridges formal/informal and/or integrates STEM disciplines and rich data capture in industry of learning-on-the-job
- Interest-driven learning was common to vignettes from all subgroups
- Mood: Participants concurred on frustrations over lack of longitudinal STEM learning data on interests, achievements, SEL...across domains and settings to support vision of adaptive integrated STEM learning
- Felt need: Importance of knowledge mapping that articulates relationships between learning progressions across multiple domains - no integrated STEM learning examples yet of such multi-dimensional curricular alignment.
- General lack of uses in STEM learning research of good/varied measurement methods for capturing multiple forms of data from which we can derive SEL* constructs related to achievement (self-efficacy, identity, mindsets).

Insights for Adaptive STEM LEADS

Figure-Ground Flip Principle*: Make world the ground learning site, bring real world STEM inquiry into schools in relation to real-world application and utility; incorporate telepresence, virtual labs**

Measurement Principles: Prioritize—
A. Long-term performance assessment - to track & support interest and STEM competency development over time;
B. Multidimensional Measurement - individual & group; SEL (interest, identity, self-efficacy, …); STEM multi-disciplinary and multi-context

Social and Generative Learning design Principle: Design for STEM engagement between learners, learners/teachers, learners/communities.
Prioritize tools for distributed expertise sharing and fostering communities of learners.

Learner Empowerment Principle: foster STEM learning agency and self-efficacy for equitable participation in learning opportunities, pursuit of one's interests

Human-Virtual Agent Interaction Co-evolution Principle: Human-VA and VA-VA interactions for supporting the development of STEM skills and competencies across settings and disciplines.

Tensions & Surprise

1. (Tension): LPs have been conceived ***within specific domains only***, yet the aim should be an ***integrated knowledge construction*** fabric woven between disciplinary topics*: e.g., we know certain math competencies are required for learning of specific topics and competencies in science, but mappings that articulate prerequisites/relationships and their integral interconnections are as yet unspecified in any standard, broadly-useful or broadly-used manner.
2. (Tension): Between capturing/storing thick multimedia data** longitudinally across settings for comprehensive learner profiling and recommended learning activities for integrated learning outcomes, but with concerns of data privacy and risks of stereotyping due to labeling.
3. Problems wrought by the inscrutability of the AI models when they make recommendations for what/when/why a learner should be learning.
4. How to avoid the "algorithms of oppression" syndrome re. diversity/inclusion.
5. Need for data interoperability for learning activities in and out of school.
6. (Surprise) Many important teacher roles ignored by AI in Education discourse.

Recommendations

Constructs that workshop groups surfaced as needing specification and cumulative knowledge building for the immediate-, near- and long-term:

1. Instrumentation goals
   a. Ubiquitous Interest Sensors (how do we capture and make sense of signals of learner STEM interest?)
2. Construct specification and measurement goals
   a. Defining central constructs of SEL such as STEM Interest, Identity, Engagement, Self-efficacy, and developing/refining robust instruments to measure them for integrative STEM learning over time
   b. Identifying, measuring STEM cross-cutting competencies (e.g., Abstraction, Modeling, Spatial Reasoning, Algorithmic Thinking, Systems Thinking, Critical Thinking)
3. Identifying STEM learning interests for students/groups/classrooms and architecture which enables adaptive recommendations for learning pathways
   a. Creation of Triggered Learning Pathway Openings based on sensings of interest and assessments 'for' learning progress (tied to topics/concepts in domains and related standards)* stemming from nodes in learners' longitudinal integrative STEM learning progressions map**
4. Defining multi-threaded learning progressions for integrated STEM
5. Integration of virtual companions in human teaching & learning environments