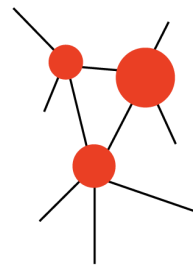


Cyberlearning Workshops: Principles for the Design of Digital STEM Learning Environments

Slides from the June 6, 2019 Workshop Leaders Summit

Held at SRI International in Arlington, Virginia

Hosted by Center for Innovative Research in Cyberlearning (CIRCL)



CIRCL

Center for Innovative
Research in Cyberlearning



This material is based upon work supported by the National Science Foundation under grant 1837463. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Weaving the Fabric of Adaptive STEM Learning Environments Across Domains & Settings ('Adaptive STEM LEADS')

PI: Prof. Roy Pea, Co-PI: Prof. Bryan Brown,
Co-Lead: Dr. Shuchi Grover
Stanford University



This material is based upon work supported by the National Science Foundation under grant **1825070**. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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	<p>‘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?’</p> <p><i>These enabled us to collectively consider new convergences, prospective collaborations, and high-priority needed developments for advancing this vision.</i></p>
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

Synthesis and Design Workshop: Principles for the equitable design of digitally-distributed, studio-based, STEM learning environments

Jill Castek (Principal Investigator)
Jennifer Nichols (Co-PI)
Blaine Smith (Co-PI)
Leslie Sult (Co-PI)
Kevin Bonine (Co-PI)
Wen Wen (Graduate Researcher)



Participants gathered at UA's Biosphere 2 Feb. 25-28, 2019



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Purpose

Studio-Based Learning Environments

(makerspaces, co-working spaces, innovation labs, fablabs)

+

Access, Equity & Inclusion

(Ways and means of carrying out inquiry through making contexts, cultures, and practices)

+

Digital/Virtual Learning Opportunities

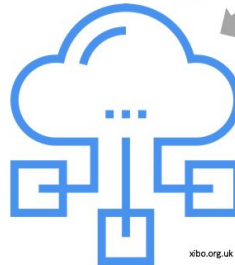
(collaboration among participants, experts, community members, facilitators, and learning guides/mentors, facilitating bi-directional expertise)

Studio-based Makerspaces



Shared Knowledge Networks

Connecting Face-to-Face and Virtually



Digitally-Distributed Networking

Equity and Inclusion



Enhanced Access

Paving the way forward for sustained efforts that span research & practice communities

Participants & Location

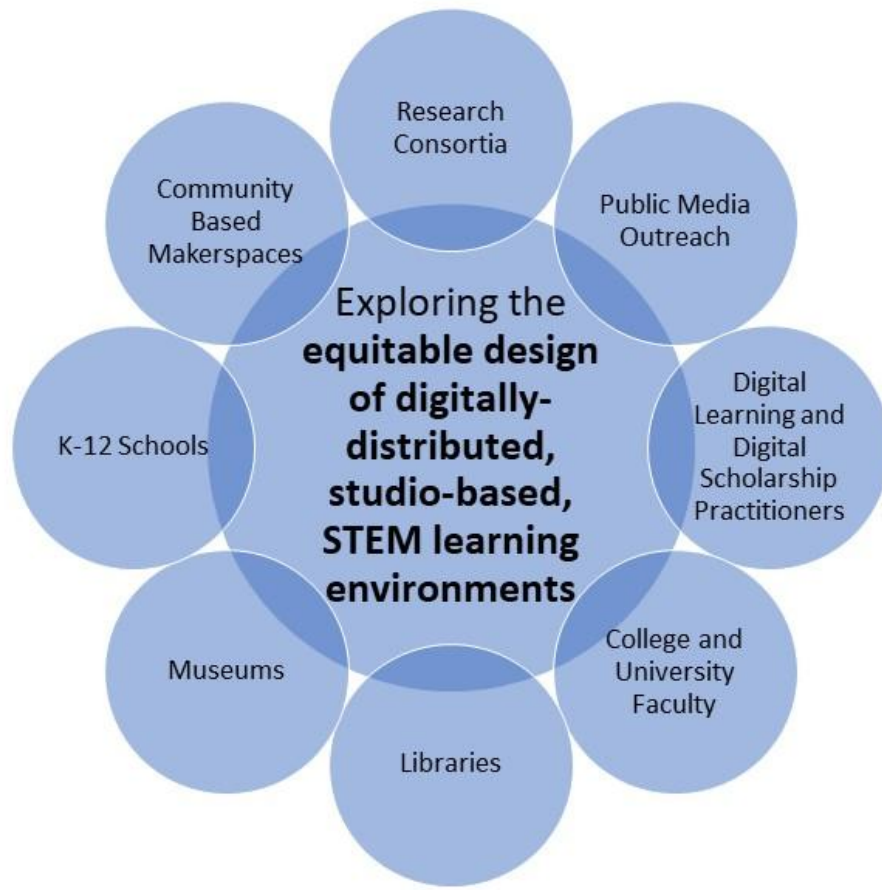


Biosphere 2 February 25-28, 2019



Iconic setting for formal and informal collaboration. *Location was a key feature that served to excite participants about state-of-the-art research, and create connections to the scientific community.*

Total Number of Participants = 63



Participants

- Libraries
- Museums
- K-12 Schools
- Community-based maker spaces
- STEM Learning Centers

Educators

Research Organizations

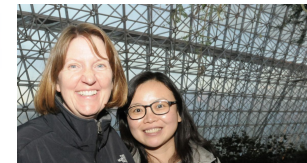
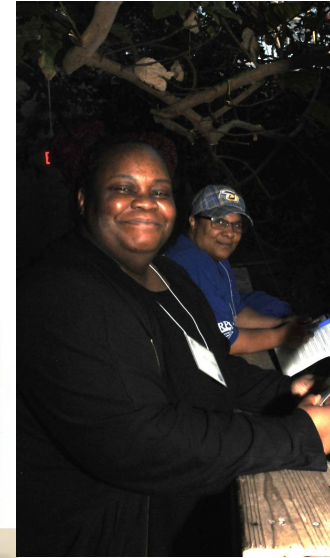
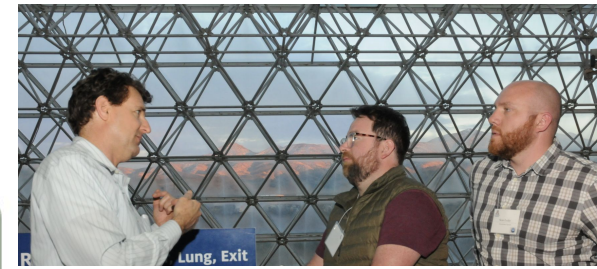
College and University

Public Media and Non-Profit Organizations

- Faculty
- Digital Learning and Scholarship

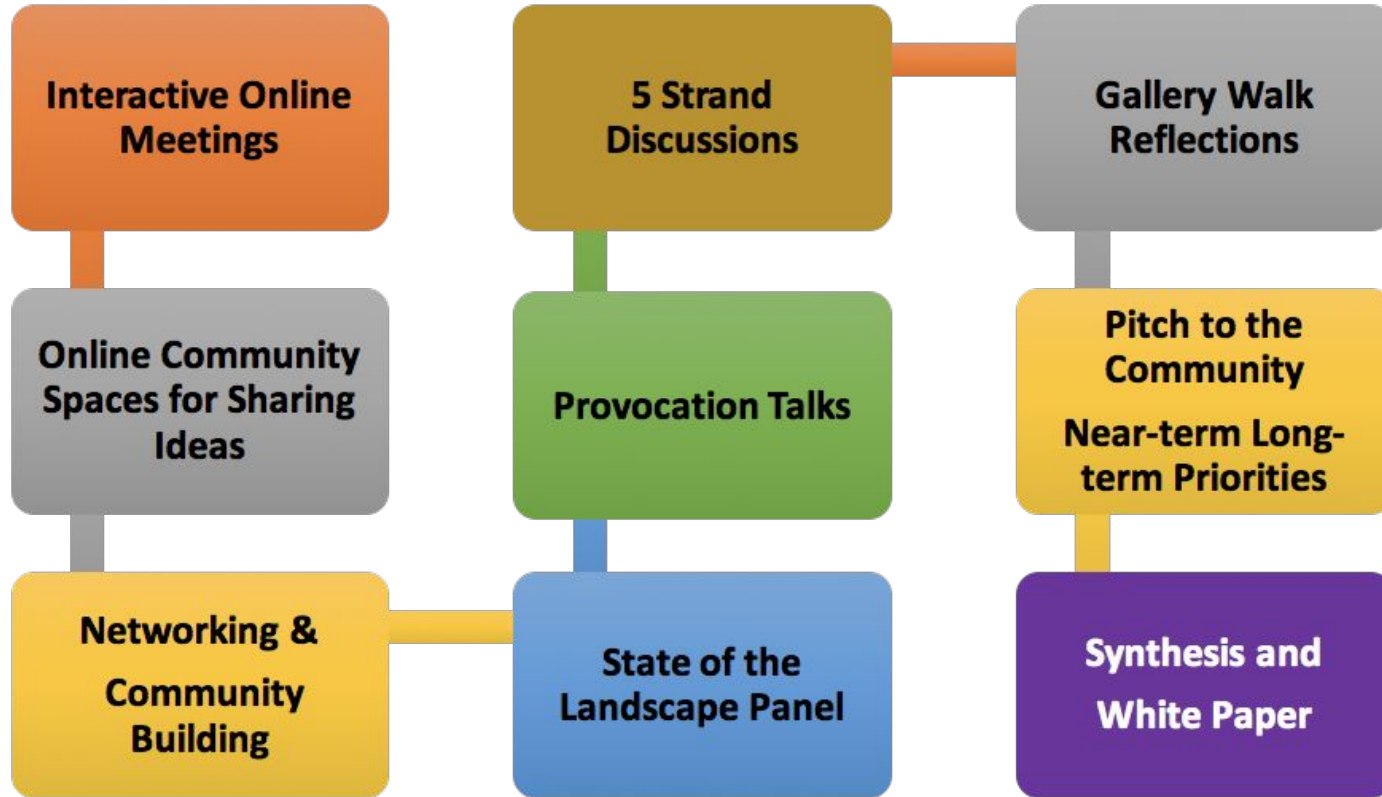
- SRI
- TERC

- KQED
- Techbridge Girls
- National Girls Collaborative
- Fab Foundation
- Maker Ed



Process

Biosphere 2: A Place of Inspiration and Innovation



Scavenger Hunt, Meal-time Conversations, Casita Time, Maker Night, Field Trips

Findings

Ecosystems Metaphor

Iterative Processes &
Complementary Assets

Interdependent
Relationships

Benchmarks &
Progress Markers

Sustainability

Atmosphere

Equitable practices create inclusive
environments



Findings

Learning Environment

Learner Equity

Spaces and their evolution

Re-appropriate resources

Community

Nurture Creative Communities of Practice

Values, Cultures and Belonging

Inquiry and Curiosity

Capturing Learning

Learner interactions

Instructional Routines

Longitudinal Data

Pedagogy & Scaffolding

Culturally Sustaining teaching and learning strategies

Studio-based learning practices of critique and cooperation

Digital Tools & Mediation

Contextual and Specific to Space and Users

Designing for Change

STEM and STEAM/Arts

Principles

Critical, Creative, Collaborative Inquiry

Interest
Driven

Peer
Supported

Relationship
Based

Interest-driven Learning

Shared
Purpose

Creation
Centered

Academically
Oriented

Transportable Skills

Practices Travel Across
Contexts

Knowledge travels
across contexts

Social and Community
Change

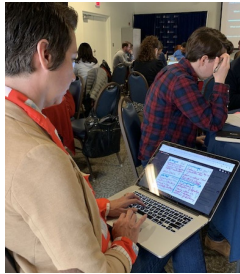
Principles

Exploration with technologies and hands-on materials;
expand problem-solving to address real-world problems



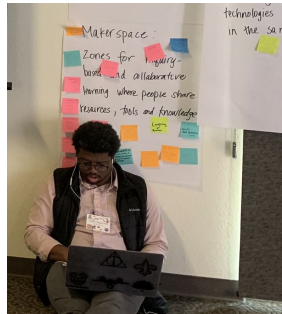
Inclusive

draw from multiple perspectives, expertise areas, shared knowledge, and experiences to **eliminate barriers and broaden access**



Intersectional

work collaboratively across communities where learners come together to **support mutually reinforcing knowledge and practices**



Innovative

use multiple technologies for learning, making, **sharing, and exchanging ideas flexibly and creatively**



Responsive

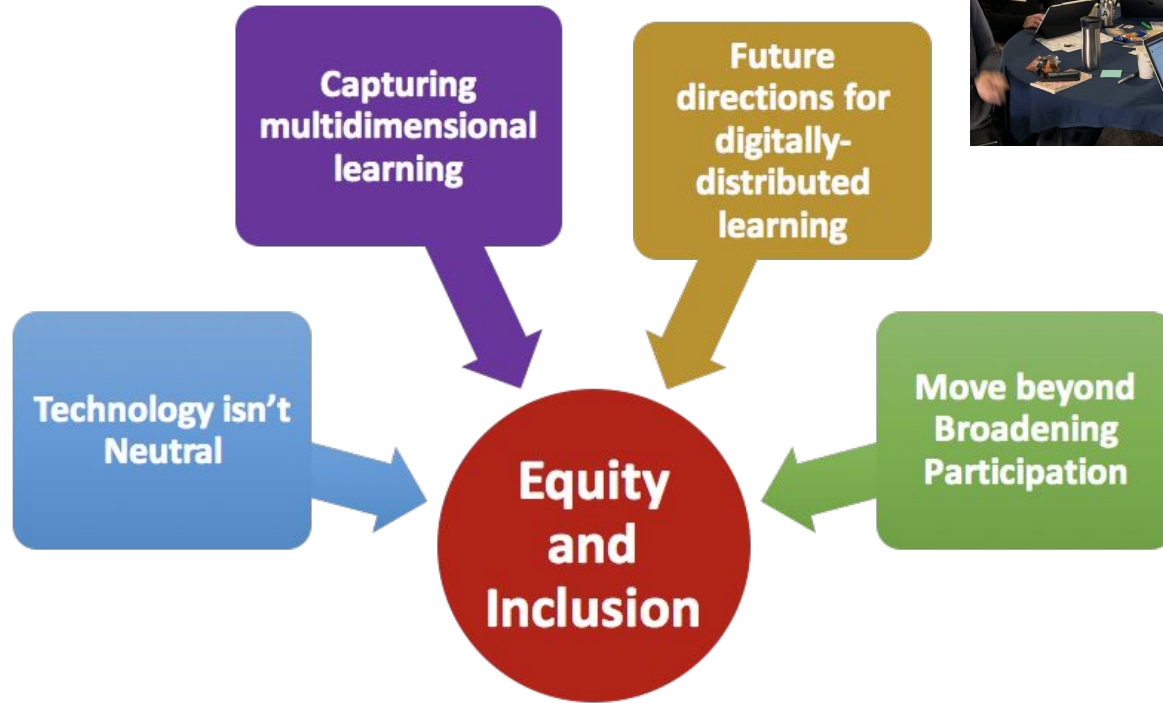
plan forward for the **evolution of spaces in response to community needs**



Transformative

create purposes for learning that **provoke and respond to changing times**

Surprises & Tensions



Practice “generous exclusion” that celebrates values of space instead of open inclusion that dilutes values (Melo, 2019).



Recommendations



Create/disseminate processes for capturing learning to examine longitudinal data

Connect research and practitioner voices to establish shared priorities

Near
Term 3-5
Years

Establish an
Equity in Making
Research
Collaborative
Network

Expand
implementation of
different forms of
digitally-distributed
learning

Track what
features/elements
act as agents of
change

Longitudinal Data
Case Studies
Learning Theories
and Models

Data to illustrate
transitions in the
learning
ecosystems as
they evolve

Longer
Term 10+
Years



Thank you!

Jill Castek

@jillcastek

Jen Nichols

@jennytnichols



We welcome continued conversations, connections and partnerships to push this work forward.

University of Central Florida

*Convened:
March 31, 2019 –
April 2, 2019*



Synthesis and Design Workshop: Digitally-Mediated Team Learning (DMTL)

Ronald F. DeMara (PI, UCF), **Laurie O. Campbell** (Co-PI, UCF), **Samuel Spiegel** (Co-PI, Colorado School of Mines), **Richard Hartshorne** (Co-PI, UCF), and **Joseph E. Beck** (Co-PI, WPI)



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Driving Question / Purpose



Which research will advance effective and scalable *digital environments* for *synchronous team-based learning* involving *problem-solving and design activities* within *grades 6-20 STEM classrooms* for *all learners*?

1/3/5+ Year Research identified via Four Parallel Tracks

- T1)** Facilitating Team Learning in Real-time via Online Technologies
- T2)** Personalizing Collaborative Learning through Analytics
- T3)** Supporting Digital Teams using Active Pedagogical Strategies
- T4)** Empowering Equitable Participation

5 Themes per Track

- a) Activity Authoring
- b) Student-Facing
- c) Instructor Orchestration
- d) XR/Gamification
- e) Indexing

Participants *84 from 44 universities*

Carnegie Mellon University	Texas Tech University
Colorado School of Mines	UCLA School of Medicine
Concord Consortium	University at Albany
Duke University	University of Calif., Irvine
Embry-Riddle University	University of Central Florida
Florida State University	University of Florida
George Mason University	Univ. of Hawaii West Oahu
Georgia State University	Univ. of Wisconsin-Madison
Georgia Tech	University of Michigan
Harvard University	UNC Charlotte
Indiana University	University of North Texas
McGraw Hill Education	University of Portland
New York Hall of Science	University of San Diego
New York University	Univ. of South Carolina
North Carolina State Univ.	Univ. of South Florida
Oregon State University	University of Tampa
Pennsylvania State Univ.	Univ. of Texas at Arlington
Pepperdine University	University of Texas at Tyler
Purdue University	University of Washington
Rutgers University	University of Wyoming
St. John's University	Virginia Tech
Syracuse University	Worcester Polytechnic Inst.

In-Field STEM:

Senior: 23%

Junior: 13%

Learning Sciences / Specialists*:

Senior : 27%

Junior : 29%

Doc Students: 8%

* Including:

Data Sciences,
Digital Media,
Medicine, MIS,
Philosophy,
Psychology,
Statistics



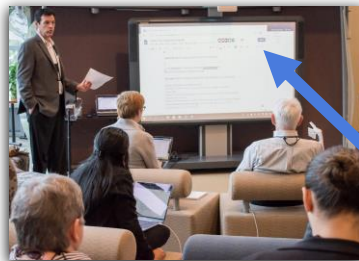
Sponsorship

- *NSF Division of Research on Learning:* DRL-1825007
- *Helmsley Charitable Trust:* meals, video/media, costs
- *McGraw Hill Ed:* reception
- *UCF CCIE, CECS, & CGS:* resources, costs



Process

*Template-Based approach to
Digitally-Mediated Collaboration*



Workshop Flow & Timeline

October - March
2018 2019

Pre-Activities

Expertise Profiles
Position Abstracts
Track Talking Points

March 31 - April 2, 2019
Orlando, FL

Workshop

Sunday 31 March 2019	Monday 1 April 2019	Tuesday 2 April 2019
Starting 3pm: <ul style="list-style-type: none">Poster SessionDemosIndustry TablesSocial Mixer	<ul style="list-style-type: none">KeynoteWorkshop OverviewParallel Tracks 1 → 4LunchParallel Tracks 1 → 4PanelTours	<ul style="list-style-type: none">KeynoteDebriefParallel Tracks 1 → 4LunchParallel Tracks 1 → 4Action Committee Formation

Qualitative Observation Protocol & Quantitative Data Analysis

April - June
2019 2019

Post-Activities

Action
Committee
Chapter Drafts

White Paper

NSF Summit

Collaboration Template

Track 1: Facilitating Team Learning in
Real-time via Online Technologies
Theme 1C: Instructor Orchestration (Ron)

State of the art for this theme:

Some challenges for this theme:

Key works related to this theme (5 to 10
citations):

1-year research objectives:

3-year research objectives:

5-year research objectives:

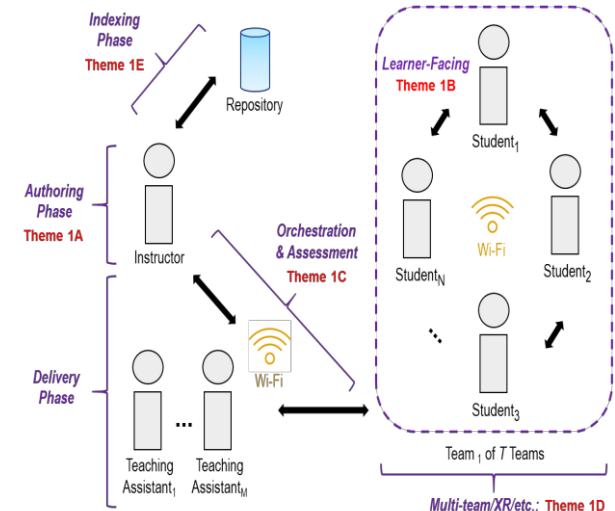


Findings

DMTL increasingly vital to the future of Digital STEM Learning



- **Numerous untapped opportunities** for online instructional environments to *engage, orchestrate, and assess* STEM design and problem-solving teams in classroom settings.
- **DMTL researchers seek to integrate/extend** the excellent interdisciplinary work done continuously since the 1980s via *feature-specific research* towards *systems impact* viewpoints.
- **Proven methods, inexpensive technology, and digitally-receptive students combine** for timely feasibility of center-scale grand challenge given widespread adoption of *mixed-mode delivery* and demands of *enrollment scalability*.
- **Attendees unanimous in the value of a roadmap for DMTL** created in a workshop setting with components/interfaces researched and then *integrated / evaluated / refined* spanning pedagogy, team sciences, machine learning, etc.



Principles

DMTL synergizes powerful learning design principles from multiple complementary research domains



1) DMTL leverages instructional technology during group problem-solving activities

- a) Learners co-construct solutions to exercises through ways of thinking (e.g. *design, computational, and systems thinking*).
- b) Team members may *adopt technical/leadership roles* and modify those during the activity.
- c) Principles of *peer teaching and learning* are enabled.

2) Instructor serves in supportive roles

- a) Technology assists instructor *observation and scaffolding* of team progress in real-time.
- b) Rapid formative feedback occurs *during the learning exercise* rather than afterwards.

3) DMTL advances equitable participation

- a) Inclusivity encompasses the *human aspects in a community of learners*.
- b) Consideration and training of *stakeholders with respect to personal and perhaps unconscious biases further increase participation* and sustainability in STEM.

Surprises & Tensions



Tension: Contrasts between K-12 vs. Higher Ed.

- *Origins:* Each domain has been independently advancing DMTL with limited cross-collaboration/exchange.
- *Perspectives:* Contrasting pedagogical knowledge in (K-12 vs. Higher Ed.) & usage in (STEM vs. non-STEM).
- *Differences:* Learner-facing interfaces and assessment benefit from distinct research varying by domain.
- *Constructive Outcome:* Participants commented in the *Workshop Survey* that interactions with diverse disciplines offered new ideas that they could put to work immediately.

Surprise: Unanimous need for Surveys, Standards, and Clearinghouses

- *Conceptual Challenges:* Nomenclature challenges of interdisciplinary roles in DMTL.
- *Existing Systems:* need to identify, classify, relate, adapt, and extend these to progress further, but how?
- *Technology Complexity:* Languages, development platforms, updates/change, and obsolescence.
- *Constructive Outcome:* Opportunity to form taxonomies, researcher-facing compendiums/standards, and instructor-facing web resource sites.

Tension: “Microscope vs. Telescope” (as promulgated by C. Dede)

Recommendations

- Immediate (*Imm*), Near-Term (*NT*), and Longer Term (*LT*)
- Based on White Paper / tables, ASEE-2019 manuscript/poster, and Exit Survey



Imm: Unify research evidence on efficacy of *real-time classroom-based DMTL across delivery modalities* (e.g. co-located, synchronous-but-seated-separately, and mobile-devices) via studies and workshops.

Imm: Assemble *glossary of inclusivity terminology, methods, and metrics* relevant to DMTL. Consider potential advances in equitable participation across the range of interactions enabled within digital teams.

NT: Create *reusable and adaptable DMTL activities with engaging learner interfaces* supporting STEM-specific tools (e.g. models, programming, equations, simulations) while employing *analytics for personalization and instructor orchestration of cooperative learning in real-time*.

NT: Create a *Virtual Innovation Center* showcasing high-impact DMTL practices, users, and an adaptable resource repository which leverages methodologies emphasizing interdisciplinary psychophysiological efforts, self-report mechanisms, and inventories to advance inclusivity.

LT: Design *new data science approaches exploring various team formations'* impact on learning outcomes.

LT: Apply and extend *ML/AI technologies within DMTL* to: (a) longitudinally suggest (or automatically construct) team learning activities personalized to the learners at-hand, (b) hybridize DMTL with Intelligent Tutoring Systems (ITS) whereby ITS agents have co-instructor roles, and (c) adapt the XR environment to spontaneously insert virtual teammates at pivotal moments, e.g. triggered by wheel spinning / wrong path.

Synthesis and Design Workshop: Distributed Collaboration in STEM-Rich Project Based Learning

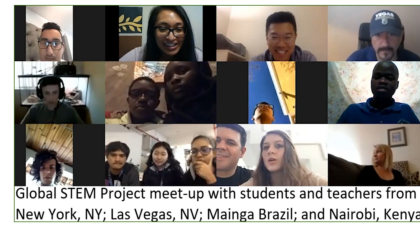
Eric Hamilton, Principal Investigator
Danielle Espino, Co-Principal Investigator



This material is based upon work supported by the National Science Foundation under grant 1824924. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



Driving Questions / Purpose



Why did we meet:

- This project's thematic area of **distributed, project-based collaboration in STEM learning** emphasizes K16 collaborations whose participants cross **cultural, national, economic, generational, STEM background, or linguistic** boundaries in ways that are new to the participants.
- In practical terms, this has entailed students working in virtual collaborations, usually with video, on substantive or complex STEM projects. The project that motivated the original proposal is an [international digital makerspace effort](#) that DRL-AISL supports, but the applications cut across all STEM education contexts, both formal and informal.
- Emerging cybertools enable the potential for distributed collaboration, especially boundary-crossing collaboration, to function as *a natural, abundant, and seamless aspect of next generation STEM learning*.
- This type of learning setting offers the opportunity to reach some of the most elusive goals of the national STEM education enterprise.

The purpose of this workshop is thus to frame a research agenda NSF can use that will articulate:

- **foundational research issues in distributed or virtual collaboration in STEM project-based learning, and competence formation, especially when students must cross boundaries to participate in such collaborations; and**
- **important design principles for such boundary-crossing collaboration in STEM learning and competence formation**

Participants

- The workshop included an eclectic and international collection of approximately 25 individuals, excluding another five who were unable to attend but will convene later in order to revise and polish the draft output before final submission.
- Participants included prominent research methodologists, learning scientists and technologists, a highly-regarded education futurist, a university president widely published in areas essential to this topic, nationally prominent experts in computational thinking, and data scientists. Collectively, they represented education service and leadership from the US, Kenya, Brazil, Singapore, and Finland.

Process

This workshop initially entailed three webinars, in February, March, and April of 2019. The webinars helped “set the table” for the workshop that took place on 13-14 May, 2019.

The opening session of the workshop on 13 May involved a “priming” exercise. Each of three different exemplars of boundary-crossing collaboration was presented. Then, each of the core team of invitees spent 90 minutes creating a “response” presentation of 20-30 minutes addressing the five questions below. They gave these presentations over the second half of the first day and all of the second day, **spurring a lively rich discussion and a corpus of inputs for the workshop paper**. It proved an effective approach for sustained and substantive engagement of the participants. The questions each expert addressed, from the vantage of the exemplar settings and other contexts with which they were familiar, include:

- Insights on how boundary-crossing impacts learning
- Theoretical directions/frameworks (“What existing frameworks that can be built on? How do we develop theoretical gravitas around boundary crossing? Who are most influential thinkers in this area that we have not yet evoked?”)
- Curiosity around this topic (“What questions are emerging from these exemplars and your colleagues’ presentations?”)
- Ideas for future learning environments (“What is the potential for boundary-crossing impact in learning?”)
- Intersection of boundary-crossing with current work (“How does your work pertain to, inform, or contribute to synthesis and design of this construct?”)



Findings

- Heterogeneous (i.e. boundary-crossing) STEM problem-solving contexts were routinely reported to elicit sophisticated STEM learning and complex reasoning. That is, diversity of participation in trust-rich contexts appears to stimulate diversity of applied reasoning.
- Virtual collaboration in STEM problem-solving that takes place in ways that lead students to cross new boundaries routinely elicits complementary sentiments of curiosity, pleasure, and joy in learning - in addition to STEM learning and competence formation.
- Interest-driven creator theory may prove an important aspect of driving collaborations envisioned as a routine aspect of future learning environments.
- Cyber-enabled boundary-crossing is important in areas such as cultural, national, or economic categories, enabling a metaphor of **virtual migration of students to a shared space**.
 - This important metaphor also applies to students who are alienated or otherwise withdrawn from learning, even if they do not otherwise appear outside of the boundaries of their learning setting. This is one of the most crucial re-conceptualizations of boundaries in the workshop.

Principles

The workshop participants either presented or conjectured on many design principles that reasonably belong in a high-end research agenda. Two of the most salient:

- Building a testable research agenda with live instancing in this thematic area requires **theoretical clarity around constructs such as boundaries, barriers, virtual presence, virtual migration, cultural competence in online settings, and boundary objects**.
 - Such theoretical clarity will enable attention to important variables such as intercultural scaffolding for different phases of virtual collaboration and learning mechanisms within boundary-crossing.
- Participants repeatedly converged on building **social trust** as a crucial or transcendent factor or variance account in virtual collaboration that crosses new boundaries for students.

Surprises & Tensions

- Every workshop participant's conceptual model of boundary-crossing significantly expanded.
 - The workshop theme is more substantive and consequential than the organizers envisioned.
- Participants who did not feel they fit into the workshop's academic setting and who did not quite understand the role they should assume in the workshop - since papers in advance were explicitly discouraged, and instead created on-site to respond to the exemplars - proved especially engaged and invested in the work of the workshop. This technical detail is a small metaphor of the subject of the workshop.
- Important philosophical considerations that are of little relevance in production style and bounded classroom settings become richer and more germane in settings that have fewer boundaries.
- "If everything is a boundary, nothing is a boundary" ~ this aphorism by one of the participants helped reinforce the importance of theoretical clarity in defining the new boundaries students can cross in envisioned future learning settings.



Recommendations

Short-term

- Examine linkages between cognitive/social/affective dimensions of virtual STEM project-based learning collaboration settings. If possible, incorporate biometrics as a research strand.
- Provide theoretical specification to collaborative artifacts and intermediate outputs as boundary objects.
- The workshop participants have agreed to develop a set of essays or special issue proposal to articulate issues emerging from the workshop.

Medium-term

- Explore distributed collaborative learning in other contexts such as gaming and social media.

Long-term

- Reconceptualize virtual learning spaces to capture newly emerging technologies (e.g. collaborative VR, biometric data), roles (e.g. creators, participatory teachers), and processes (e.g. new forms of interaction).



The Future of Embodied Design for Mathematical Imagination and Cognition

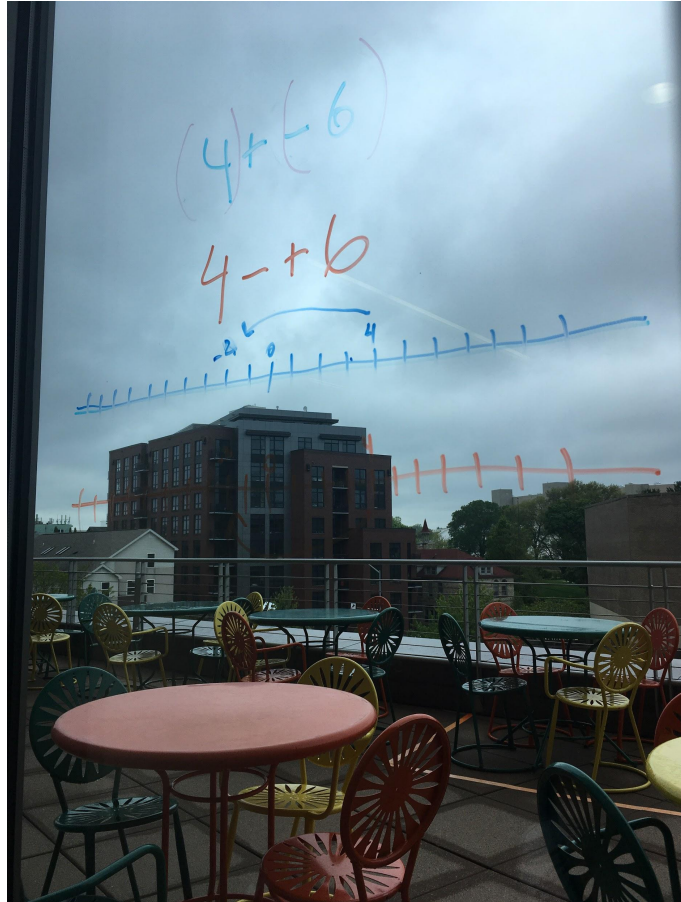
Leader: Mitchell J. Nathan

Co-Leaders: Dor Abrahamson, Martha W. Alibali,
David Landy, Erin Ottmar, Hortensia Soto, Candace
Walkington, *Caro Williams-Pierce*



This material is based upon work supported by the National Science Foundation under grant 1824662. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Driving Questions / Purpose



The goal is to form a ten-year research agenda that will provide a coherent set of evidence-based design principles for enhancing mathematics education and broadening participation in all STEM fields.

This driving purpose is particularly crucial due to the newness and interdisciplinary nature of the EMIC field. Represented at the workshop were EMIC experts from the fields of: learning sciences, psychology, dance and movement science, linguistics, computer science, education and special education, and mathematics.

Participants

Teachers (K-20) - Educator Roundtables (5)

Students, Postdocs, Early Career - Poster Session (19)

Faculty - Presentations (21)

Primarily from the United States - but 6 international participants

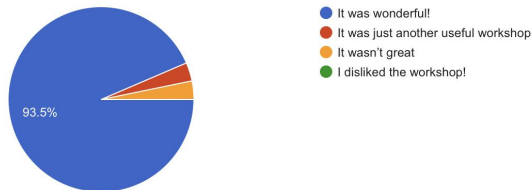


Keynote Speakers and Discussants from outside the field, to push our thinking:

- Keynote - Dr. Brian Bottge (Mathematics and Special Education)
- Keynote - Dr. Maxine McKinney de Royston (Mathematics and Multicultural Education)
- Discussant - Dr. Art Glenberg (Language and Embodied Cognition)
- Discussant - Dr. Jim Slotta (Technology and Learning)

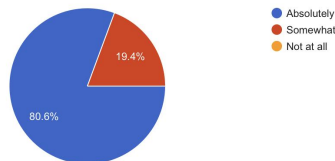
Did you enjoy your time at the EMIC workshop?

31 responses



Do you think that your future scholarly or professional work has been in any way influenced by this workshop? Such as through learning, presenting, teaching enacting, or developing new collaborations.

31 responses



I particularly liked: - the choice of keynotes (providing fresh perspectives on embodied learning) - the opportunities for colleagues at a range of career points to contribute - the inclusion of teachers

Process

- Everyone who attended led something: a presentation, a poster, an educator roundtable, and/or an embodied activity
- Activities designed to support mathematical learning through embodiment *grounded* the experience
- Organizing committee screened formal applications, reached out to invited presenters. Almost all accepted participants fully funded to attend

Because everyone participated in some form, the workshop had a greater sense of collaboration and investment than other experiences I've had.

Size and mix of talks, activities, breaks was perfect - I feel I got to meaningfully interact with almost everyone there.

As a teacher, I found this invaluable. I have been pushed to think of education in a whole new light. ... I have made connections with impressive people who look to enhance the face of learning. I am in awe of the work they do. What was so humbling about this week was the fact that these incredible people wanted to hear my voice. They wanted to listen to the challenges I face and celebrate the growth I experience. I cannot thank these organizers and participants enough for helping me emerge as a stronger, more well-rounded educator.

Findings

Research: lively discussions that reflected the many diverse and complementary methodological considerations of this emerging inter-discipline.

Theory: leverage interdisciplinary connections into a coherent collective voice that identifies consistent learning principles that inform Embodied Design for Mathematical Imagination and Cognition (EMIC), while preserving the distinct disciplinary identities.

Practice: consider how EMIC perspective broadens STEM participation for those minoritized and differently abled; increase awareness for gesture as signifying content-related communication; consider the classroom environment, curricular objects, and teacher needs when introducing technology; enable movement; begin from intuition.

Theory-Practice Relations: there was a distinct sense of urgency for participatory design, and an emphasis on the need to keep including teachers when we are designing experiences for the classroom. Particular need for evidence that gesture facilitates learning and instruction.

Reflection, Planning, and Resources: we need to strategize for community development, intellectual cohesion, identity, longevity, and impact.

Principles

71% (n = 22) definitely agree with: *More experimental evidence is needed to pinpoint the specific interactions between students, subject matter, and situated, grounded and embodied curricular design.*

67.7% (n = 21) definitely agree with: *I operate under the assumption that all cognition is inherently embodied.*

61.3% (n = 19) definitely agree with: *I am still learning about cognition, and how we learn.*

[I use principles from the field of] Gesture Theory - 75%

I consider social emotion to be something that can impact conceptual integration - 62.5%

[I use principles from fields that focus on designing] dynamic gesture-based interfaces for mathematics - 56.25%

[I consider that] dynamic gestures allow participants to physically experience generalized properties through enactment - 56.25%

[Learners should] “experience first, signify later” - 56.25%

We should encourage physical and spatial exploration of the structure of algebra - 50%

[I use principles from the field of] Distributed Cognition - 50%

*I primarily or
sometimes use
frameworks by:*
Alibali
Nathan
Lakoff & Nunez
Abrahamson

Surprises & Tensions

There are unanswered questions regarding different types of embodiment that need investigation - 84.38%

Teachers are professionals that should be deeply involved in developing, adopting, and adapting embodied learning activities - 81.25%

There are unanswered questions regarding working with practitioners that need investigation - 75%

Teachers should be able to adopt and adapt body-based learning activities - 75%

Activities should be designed to leverage our naturally occurring perceptions towards conceptual understanding - 71.88%

What counts as math (and who decides) is a constant tension in this interdisciplinary field - 62.5%

There are unanswered questions regarding research practices that need investigation - 59.38%

*Dance and Math!
Frickin-Ay!
Who knew?!*



Recommendations

Immediate Applicability:

- Talk about EMIC research with everyone you know
- *We have immediate plans to redesign www.embodiedmathematics.com*

Near-Term:

- Cultivate K-20 teacher-researcher-policymaker partnerships
- Promote opportunities to share and curate empirical inquiry into the conditions for designing EMIC for instruction, assessment and learning environments
- Investigate how EMIC addresses equity in our classrooms

Longer Term:

- Consolidate and integrate so that we have a stable, shared theory
- Promote a long term commitment for funding research on embodied cognition, instruction, and assessment practices

Requests to continue holding regular EMIC workshops were included in all three categories by different survey respondents.

*Be theoretically rigorous,
be proud,
be brave,
stick with EMIC.*

DCL: Synthesis & Design Workshop: Designing STEM Learning Environments for Individuals with Disabilities

AccessCyberlearning 2.0

PI: Sheryl Burgstahler, Ph. D.



This material is based upon work supported by the National Science Foundation under grant #1824540. Any opinions, findings, & conclusions or recommendations expressed in this material are those of the author(s) & do not necessarily reflect the views of the National Science Foundation.

Driving Questions / Purpose

1. **What challenges** do students & instructors with different types of disabilities face in using current & emerging cyberlearning tools & engaging in cyberlearning activities?
2. **How do current digital learning research & practices** contribute to the exclusion & marginalization of individuals with disabilities?
3. **What advances** in design are required to support cyberlearning that is accessible to, usable by, & inclusive of students & instructors with disabilities?
4. **What specific actions** can digital learning researchers, educators, funding agencies, & other stakeholders take to systematically address cyberlearning access issues with respect to disabilities?

Participants

- Thus far, 22 individuals have directly contributed to the development of the white paper through our workshop & community of practice; by the end of the project more than 150 individuals will have had opportunities to provide input.
- Participants include individuals with disabilities, cyberlearning technology & pedagogy researchers, computing faculty & doctoral students, cyberlearning instructors & designers, leaders of K-12 & postsecondary cyberlearning projects, IT accessibility experts, & Center for Innovative Research in Cyberlearning (CIRCL) staff.

Process

At the workshop & in an online community of practice, collaborators:

1. **Synthesize & integrate** existing research relevant to the accessibility of digital learning to students with a variety of disabilities.
2. **Produce a white paper** which addresses research questions & contributes to the development of forward-looking, highly adaptable, distributed, collaborative, digital environments that can personalize learning for diverse learners that include individuals with disabilities.
3. **Develop guidelines** for how researchers & educators can address disability/accessibility-related issues with respect to (a) designing & testing new technologies, (b) analyzing & reporting outcomes, & (c) designing project activities & resources.

Findings

- US civil rights legislation requires access to educational opportunities, including those that make use of IT, to students with disabilities (K-12 & postsecondary: Section 504 of the Rehabilitation Act of 1973, Americans with Disabilities Act of 1990 & its 2008 Amendments; K-12: Individuals with Disabilities Education Act).
- There is little evidence that cyberlearning technology & pedagogy research & practice routinely address access issues for individuals with disabilities.
- Established principles, guidelines, & practices currently exist to guide the development & use of accessible, usable, & inclusive cyberlearning technology & pedagogy.

Principles

Principles that can guide the accessible design & practice of cyberlearning technology & pedagogy include

- 7 principles of universal design (UD) of the National Center on Universal Design,
- 3 principles of Universal Design for Learning (UDL) established by the Center for Applied Special Technology (CAST), &
- 4 principles of the Web Content Accessibility Guidelines of the World Wide Web Consortium (W3C).

Surprises & Tensions

- Disability is not always addressed as a diversity issue, even in projects focused on broadening participation.
- Many cyberlearning products being developed may not comply with civil rights legislation under which educational institutions are covered entities. At current rate, more than 500 complaints per year are filed with the US Department of Education Office for Civil Rights over inaccessible technology.
- To achieve systemic change toward more accessible, usable, & inclusive cyberlearning, multiple stakeholder groups must be engaged (e.g., researchers, instructors, instructional designers, computing faculty, IT companies, funding agencies).

Recommendations

- **Immediate:** Develop & share guidelines for the accessible design of cyberlearning tools & pedagogy; develop & offer training & resources tailored to cyberlearning researchers, educators, & other stakeholder groups regarding the engagement of people with disabilities & their perspectives & the application of UD, UDL & WCAG principles in their work.
- **Near-term** (3-5 years): Continue developing resources & offering training to stakeholder groups; for researchers, promote inclusion of accessibility issues in their workflows (e.g., consider the needs of *all* learners when designing research & instruction; include individuals with disabilities in research studies; share results for people with disabilities in reports.)
- **Longer term:** Researchers routinely implement an iterative design process that includes users with disabilities in all phases of the research.



Scalable Advanced Learning Ecosystems

Stephen Harmon (PI) / Rob Kadel, Yakut Gazi, Ashok Goel (Co-PIs)



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DRIVING QUESTIONS / PURPOSE

Bring together researchers, administrators, and faculty to discuss, brainstorm, and share strategies for the creation of a cost-effective, sustainable, and scalable educational environment. The project team refers to this as a Scalable Advanced Learning Ecosystem (SALE).

- Identify the overarching issues that need to be addressed in creating a system of learning that is both highly personalized and scalable.
- Examine learning and organizational goals, affordances of new and emerging technologies, institutional strengths, and societal drivers of change that coalesce in the creation of SALE.
- Consider project scale, scope, costs, potential impact, and possible return on educational investment.



PARTICIPANTS = 55 EDUCATORS FROM AROUND THE COUNTRY

Organizations Represented:

Georgia Tech
Harvard
University of Colorado
The Smithsonian
University of Texas at Austin
University of Texas at Arlington
University of West Florida
Bill & Melinda Gates Foundation
University System of Georgia
Emory University
A.T. Still University
Virginia Tech
TU Delft
UNC Charlotte
IMS Global
Central Michigan University
Valdosta State University
UMBC
WebStudy International
Gwinnett Online Campus

Disciplines Represented:

Engineering
 Civil
 Environmental
Education
 K-12
 Higher Education
 Learning Sciences
 Professional Education
 Administration
 Research and Innovation
Economics
Psychology
IT
Natural Sciences
Computing
Modern Languages



PROCESS

The summit was organized around five working groups:

1. business models;
2. technical infrastructure;
3. immersive learning, such as augmented and virtual reality;
4. artificial intelligence and personalization; and
5. research, assessment, and insights.

Each of the groups was tasked with a series of questions to consider and was asked to use those questions to create visions for the future of a SALE in 1-2 years, 3-5 years, and 6-10 years.

Pre-Readings
Plenary Sessions
Facilitated Breakouts
and Reports

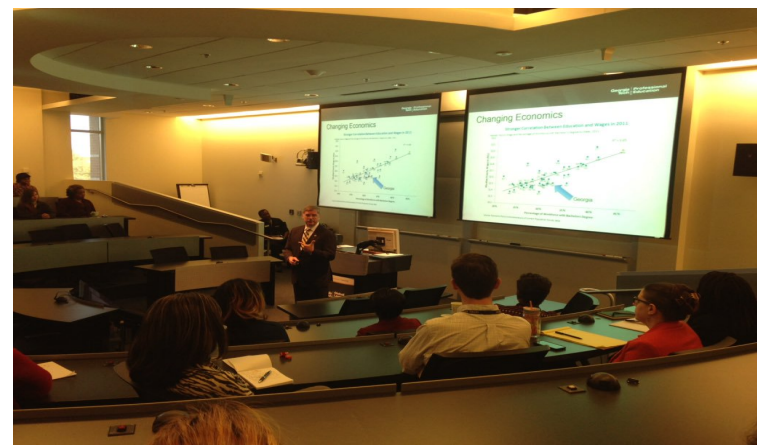


CREATING THE NEXT

FINDINGS

Five themes emerged from the summit:

- 1) enhanced learner agency;
- 2) transformation of instruction, assessment, and the faculty role;
- 3) rethinking accreditation, financial aid, and the credit hour;
- 4) moving towards a complex and interconnected technical infrastructure;
- 5) affordability and determining return on educational investment.

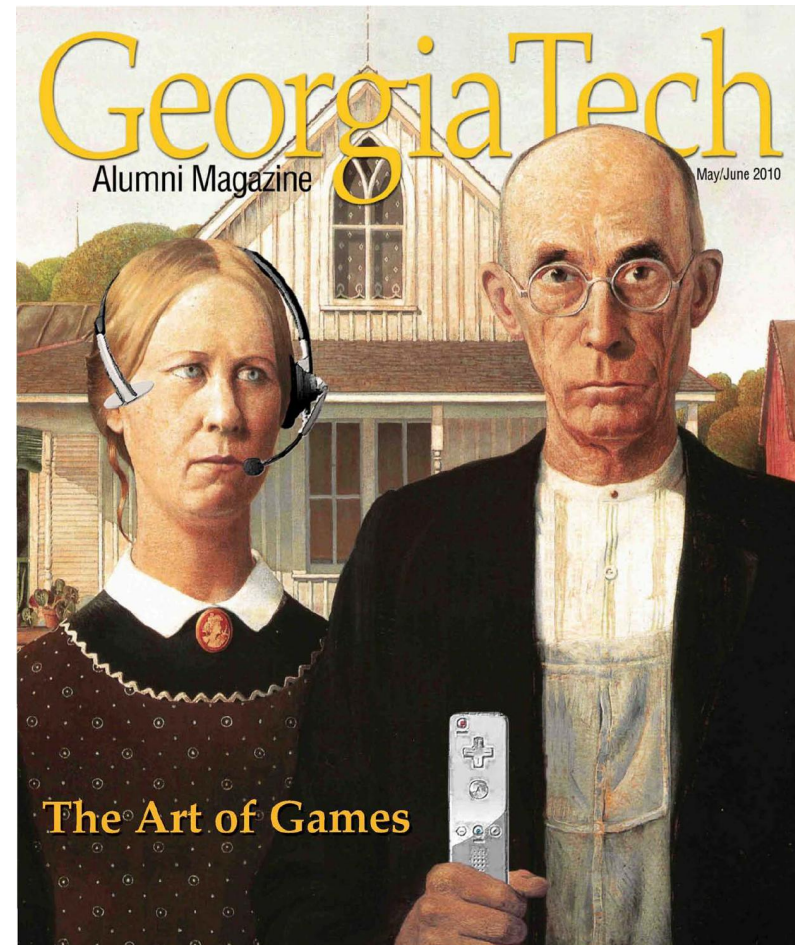


SURPRISES & TENSIONS

Great opportunity exists for scaling education through open knowledge networks such as those at the Smithsonian Institution.

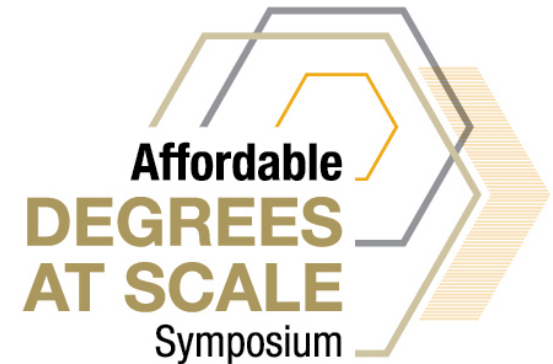
There is a need and desire to target learning not only towards acquisition of knowledge and skills, but also towards change in behavior including agency and empowerment.

There are a lot of similarities between SALEs and Next Gen Digital Learning Environments (NGDLE). Some tension may exist , because we are proposing another framework for the same issue that NGDLE attempted to solve.



RECOMMENDATIONS

1. Need to Challenge existing educational products
2. Need a Change in faculty role
3. Need a “Dewey unit” to measure “experiential learning” in and out of classroom
4. Higher Ed needs to address a deepening ROI problem
5. Need to create a Lifetime record of learning - Comprehensive Learner Record (CLR)



PRINCIPLES

- Business models and scale must inform NGDLEs. Business models and scale go hand-in-hand.
- SALEs must be built using a systemic approach (e.g. Learning Tools Interoperability (LTI)).
- Vulnerabilities in governance (e.g., policy-making, data, and faculty roles) must be addressed.
- Institutions will need to pursue their own niche



Research Priorities in Learning Analytics

Principle Investigators:
Stephanie Teasley & Rada Mihalcea
Senior Scientist: Henry Kelly
University of Michigan



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Driving Questions / Purpose

Which areas of research are most likely to leverage modern data analytic tools in addressing critical questions in learning:

1. How can we define the educational outcomes, competencies, and habits of mind that are goals for HE?
2. How can these competencies be measured and communicated?
3. How can innovations in approaches to learning (tech & pedagogy) be evaluated?

Invited Workshop Participants

- **Academia:** Faculty with backgrounds in education, data analytics, information, and other areas
- **Industry:** Researchers in businesses providing services in people analytics, recruitment, and job placement
- **Non-Profit:** Representatives of NGOs exploring new approaches to defining, measuring, and communicating competence and skills

Process: 2-Day Workshop

- Introductory session outlined the purpose of the workshop and a brief overview of the topics to be covered (public)
- Two short talks on each of the three topic areas by academic and corporate experts (public)
- Two breakout sessions on each topic area chaired by speakers (private)
- Working dinner with invited speaker for “Reflections of the Landscape”(private)
- Breakout sessions resume for consolidating ideas (private)
- Plenary session discussing breakout session results and outlining next steps (public)

Findings

Teasley & Kelly, UM

- Universities and other post-secondary institutions are not providing prospective employers sufficient/relevant information about their students, including measures of competence (e.g. what they can do vs. what they know) and soft skills. Although employers don't know exactly what they do want...
- There is a demand for 21st century alternatives to standard transcripts and degrees, and increased emphasis on workforce-related skills.
- “People analytics” tries to fill this void using sophisticated data management tools. But this work has not been well documented in the academic research.
- Huge volumes of information are now available about students and workplace performance that can improve the way competence is defined and measured. But dangers lurk: privacy, training AI with biased data.

Principles

- Universities and companies must improve ways to define competencies actually valued in the workplace. New analytics tools can help define characteristics of successful employees.
- New instructional methods can test and communicate a rich set competencies that have meaning for students, employers, and instructors.
- Simulations, apprenticeships, and other strategies can both enrich learning and produce data that can be used to measure a sophisticated range of competencies.
- Competencies should measure what a person can actually do regardless of where skills were acquired— measure outputs not inputs (e.g., courses taken).

Surprises & Tensions

- Issues were often more organizational tensions in HE than tech barriers.
- University and corporate research groups were often not aware of the scope or sophistication of each other's work.
- There is strong commercial interest in recruitment tools that remove biases (race, sex, others) from the process. Can algorithms be more objective than people?
- There was clear concern that automation would replace human judgement in education and that new tools would undermine university goals not linked to employment. Liberal arts might be undervalued. (Although some data shows that liberal arts skills are highly correlated with employment success)

Recommendations

CISE and EHR should find a way to support initiatives in the use of data analytics tools in post-secondary education and encourage academic/corporate collaboration. This would include research directed to:

- Create tools to define the competencies actually valued in the workforce by different employers. Build tools for tracking graduates.
- Address the pathways through and across careers, and the infrastructure needed to support life-long career paths (e.g., “up-skilling”).
- Explore and test valid measures of these competencies, and explore the correlation between these measures and actual workplace performance.
- Explore use of new analytic tools to design instructional systems that can continuously improve based on measured gains. New approaches would include both new technologies (simulation, machine learning), and a range of new strategies – including new ways of combining work and formal instruction

Digital Science and Data Analytic Learning Environments at Small Liberal Arts Institutions

John Symms, PI, Jane Hopp, co-PI,
Charles Byler, Organizing Committee Chair
Kathleen Coutley, Project Coordinator



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Driving Questions / Purpose

The primary goal of the workshop is to form a consortium of small liberal arts colleges that work to support expansion of usage of and development of NGDLE's for teaching data science and data analytics. The consortium will address four research questions: (1) How will NGDLE's prepare students for employment that requires DSA? (2) How will the design of DSA NGDLE's account for the variability of learners? (3) How will NGDLE's be assessed to measure student DSA competency? (4) How will a national consortium for digital learning at small liberal arts institutions form and function to sustain and expand the workshop outcomes?

Participants

School	Team Compositions																Interests			
	M	CS	NS	BU	ED	SS	DS	AH	IT	NG	HS	DE	AS	DH			AC	GE	M	G
Carroll University (Wisconsin)	1	1		2						1							X	X	X	X
Drury University (Missouri)	1		1	1		2											X		X	
Emmanuel College (Massachusetts)	1	1				1				1		1							X	
Franklin University (Ohio)	1									2		1	1				X	X	X	X
Hiram College (Ohio)	1	1		1	1				1								X	X	X	
LaGrange College (Georgia)				2		1			1			1							X	
Merrimack College (Massachusetts)		1		1					1	1		1					X	X	X	X
Pacific Lutheran University (Washington)				3			1		1									X	X	
Presbyterian College (South Carolina)	1			2		1	1												X	
Ripon College (Wisconsin)	1								1	1			1		1				X	
Seattle Pacific (Washington)	1	1	1												2			X	X	
	8	5	2	12	1	5	2	1	5	5	0	5	1	3			5	6	11	3
	M = mathematics																AC = across curriculum			
	CS = computer science																GE = general education			
	NS = other natural science																CE = certificate			
	BU = business, accounting, economics, information systems																M = Major/Minor/Certificate			
	ED = education																G = Graduate			
	SS = other social sciences																			
	DS = data science, analytics																			
	AH = arts & humanities																			
	IT = IT specialist																			
	NG = NGDLE's or academic technology																			
	HS = health science																			
	DE = dean or provost																			
	AS = assessment director																			
	DH = digital humanities, digital librarian, other librarian																			

Process

- Internal and external advisory committees did semester long plan for workshop facilitated by a global management consulting firm (Silver Rock Consulting)
- Five presentations: one each on data science, team science and learning science, two on NGDLE's (one on open source resources and one on IBM offerings, e.g., Watson)
- Based on interest (major/minor or gen ed), institutional team members were randomly assigned into one of 8 teams
- Teams worked on content areas after each talk, building consortium buy-in and common goals
- Individuals volunteered to commit to one of six consortium goals at end

Findings

- Based on institutional applications (44 total), data science and data analytics are of interest to but there is need to develop expertise at small liberal arts institutions
- Similarly NGDLE's and team science are of interest to but there is need to develop expertise at small liberal arts institutions
- Team science can help inform how the consortium functions
- A consortium can assist small colleges in expanding the needed expertise

Principles

- Need to expand universal design knowledge
- Need to expand consortium to include partners with more NGDLE and data science expertise
- Need to utilize team science to kick start continued consortium work

Surprises & Tensions

- Some participants were forced to be there
- Continuing work after the workshop is the greatest challenge
- Team science became the unifying theme in the workshop

Recommendations

- Immediate: Second facilitated workshop in August 2019 consisting of 20 consortium individuals representing 11 IHE, industry, and content experts. Workshop goals: 1) Assemble clear and concise narrative for consortium initiative, 2) Establish cadence for ongoing status reporting and progress checkpoints, 3) Identify innovative prototype projects and workstream group outcomes to be implemented over next 3 years, 4) Annual consortium meeting focused on workstream group outcomes and prototype projects.
- Near-term: 1) Implement innovative prototype projects and workstream group outcomes over next 3 years, 2) Funded consortium.
- Longer term: Expand consortium members and prototype projects.

Working Group on Instrumented Learning Spaces

Yoav Bergner & Anne-Laure Fayard



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Driving Questions / Purpose

Collaborative learning in the real (vs online) world is notoriously difficult to assess. Ethnographies do not scale, and frequent surveys are disruptive.

Multi-modal sensing technologies are now affordable and small enough to bring into the classroom or learning environment

Understanding collaborative processes in an instrumented learning space calls on convergent expertise -- from learning sciences, from psychology, from computer science, and from design.

What will happen if we record a multi-modal data set of design activities in a makerspace using a bunch of academic researchers as both experimental designers and subject?

Participants

Backgrounds: learning sciences, human-computer interaction, organizational studies, technology

Win Burleson
Gustavo Almeida
Xavier Ochoa
Kayla DesPortes
Mike Tissenbaum
Veronica Newhardt
Lin Lin
Matthew Berland
Marcelo Worsley
Tom Moher

Bertrand Schneider
Yoon-Jeon Kim
Caitlin Martin
Peter Wardrip
Ingrid Erickson
Dani Herro
Paulo Blikstein
Robb Lindgren
Luke Dubois
Liz Gerber
Noel Enyedy

Anne-Laure Fayard
Yoav Bergner

Process

Pre/post in-person event

Four sub-groups: **Constructs, Tasks, Instrumentation, Data**; virtual meetings co-ordinated by subgroup leaders, with summit meetings. All documentation and planning tracked in AirTable

In-person event

Working in different four-person groups, participants designed and prototyped a cup and saucer in the NYU Tandon Makerspace. Skeleton tracking, multi-channel audio, and radio-located positions were recorded throughout. Day two included reflection and planning sessions.

Findings

Multimodal sensing of individual design activities (our task) is still very challenging; our on-the-cheap approach was only partially successful, and work on audio reconstruction has turned out harder than we anticipated.

Converting research findings into actionable inputs is a delicate design issue. No one wants “clippy” for collaboration, but assistance in expertise/knowledge diffusion could help.

Being “part of the experiment” made the signal underdetermination problem salient; e.g., how to disambiguate intentions in movement

There is not enough cross-talk between research on collaboration in education and organization studies.

Principles

[New or reframed principles / insights for the design of STEM learning environments within your theme]

Instrumentation can be in competition with learning design. The technical challenges of using multi-modal sensing technologies can easily overwhelm the design efforts of instrumented learning spaces, sometimes pushing aside important questions of “purposeful evidence.”

Need to be aware of many “peripheral” factors. Makerspace support staff (TAs) are an important part of a makerspace ecosystem and dependencies related to them must be accounted for in assessment of group work and process. Design of the space itself (cultural norms) can also influence outcomes.

Surprises & Tensions

Participants found the format of a workshop where we actually built things refreshing. It enabled new insights into:

What would the data really show? Where should the camera have been?
What about all of the design artifacts we made? What about the cultural norms felt in the makerspace itself (flagship products were cars and rockets).

In the rush to create a visible design product, assigned roles and scripts were cast aside, even by (especially by?) the researchers themselves.

Recommendations

Immediate: Instrumented learning spaces will benefit from support for more communication and collaboration opportunities between organizationists, educationists, and technologists.

Near-term (3-5 years): Assessment and measurement models for project-based learning environments can take innovative forms when coupled with multi-modal data streams. We need to explore richer socio-techno-cognitive models.

Longer term: What we measure affects what we do (in a makerspace). Let us try to make sure we are setting up to count what should count.



Cross-disciplinary Research on Engaging Advanced Technology for Education (*CREATE*)

NORTHERN ILLINOIS UNIVERSITY

Robots, Young Children, & Alternative Input Methods

Yanghee Kim, Workshop Organizer

Professor & Morgridge Endowed Chair

Director, *CREATE* Center, Northern Illinois University



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Background

Kindergarteners' rich multimodal and multisensory interactions with robot.



Driving Questions / Purpose

To bring cross-disciplinary experts to understand the current status of designing and evaluating child/robot collaborative systems:

- What are *the current status* of research and development in child/robot interaction?
- What are *the core theoretical perspectives* that may guide research in this area?
- What engineering assistance could expedite critical research issues for developing child/robot interactions?
- What technologies are available in these areas?
- What are the challenges in developing such technologies and research programs?

Process Outline

- Selected and invited top researchers through scholarly/professional works and recommendations by an NSF officer
- 15 invited presenters & 30 participants

During the one-and-a-half-day workshop:

- Day 1- Knowledge sharing: individual presentations grouped by social robotics, cognitive and learning theories, visual data processing, ASR & dialog generation, and ethnographic observation.
- Day Two- breakout group discussions: 1) Robot 101 (Platforms & User Experiences), 2) Speech technology, 3) Content authoring.
- Group leaders contributed summaries to the final report.

Invited Presenters

- Breazeal, Cynthia, personal robots, MIT Media Lab
- Huang, Lixiao, social robotics for ASD children, Duke University
- Kim, Yanghee, child/robot interaction design, Northern Illinois University
- Qi, Xiaojun, visual data processing, Utah State University
- Ramani, Karthik, engineering embodiment and automation, Purdue University
- Aaron, Kline, multimodal interaction assessment, Stanford School of Medicine, Pediatric Research
- Alexander, Ajith, speech recognition and diarization, Oxford Wave Research
- Alwan, Abeer, automatic speech recognition and analysis for young children, UCLA
- Walker, Marilyn, computational linguistics (dialog generation), UC Santa Cruz
- Tony Zhao, dialog generation system (*Dialport*), Carnegie Mellon University
- Dorsey, Chad, speech technology in classrooms, Concord Consortium
- Han, Insook, Embodied cognition, Temple University
- Daro, Vinci, Social-emotional learning, Stanford Center for STEM Learning
- Kim, Kyung, Text analysis in group collaboration, Northern Illinois University
- Yoon, Jiyeon, Early science learning, University of Texas at Arlington
- Johnson, Laura, Qualitative Research (Ethnography), Northern Illinois University

Findings & Insights

1. A large number of effective designs have been developed.
2. Effectiveness of designs often exceeds expectations, & several unanticipated phenomena are observed (e.g., children's spontaneous physical actions and strong affective responses).
3. CRI is the field, more than any other in the Learning Sciences, that gathers and analyzes data of different modalities in parallel.
4. Designs are specialized; for example, robot designs to support cross-cultural communication, to help children with Autism, to support STEM learning.
5. Several theories are leveraged for design; but few efforts made to further advance such theories nor to develop the more general guiding theories.

Design Principles

CRI design to leverage children's natural way of learning and development:

1. Invite children to be active participants in playful learning; children are initiators with a sense of agency.
2. Embed robotic interaction within age-relevant meaningful narratives.
3. Integrate explicit exchanges of emotions verbally and physically ("I love you," and hugging).
4. Embrace embodied interactions: bodily movements & gestures as a valid form of engagement for learning and development.
5. The robot's mistakes are an effective tool for creating children's voluntary engagement.

Surprises & Tensions

1. CRI is such a powerful tool to engage children in desired activities, especially for those in need.
2. Rare attempts to construct encompassing frameworks for design or interpretation of interaction data.
3. Limited insights into children's spontaneous, earnest interactions, views, orientation towards the robot.
4. Urgent need for advancing computational approaches to automating data analysis; however, severe lack of children's multimodal data.
5. A vast majority of research relies on lab trials with pre/post tests, providing limited practical implications.
6. Lacking acknowledgement of the importance of educational and learning scientific perspectives.

Recommendations

Aligned with *Convergence Research, Harnessing Data, INCLUDES, Future of Work*, support/demand cross-disciplinary collaboration for research and education.

1. Establish standing research communities at primary venues (e.g., AERA, ISLS, HRI) for continual engagement in this area.
2. Highlight the need for in-vivo studies & multimodal data collection for valid assessments.
3. Fund course offerings, e.g., Humanoid Robots 101.
4. Inform about the potential of robots for diversity and inclusion:
 - Robot as a cultural broker,
 - Robot as a teaching assistant,
 - Robot as a peer learner,
 - Other roles