Abstract

Recently, a national center for innovative research in learning with technology coordinated 11 independent scientific workshops. Each independent workshop invited 20-60 participants to explore existing findings and forward-looking recommendations at the intersection of learning sciences, emerging technologies, and equitable opportunities to learn. Afterwards, workshop leaders held a one-day summit to interrogate common themes: emerging classes of learning technologies (e.g., social robotics, studio-based learning, boundary-crossing collaborations); important forms of learning (collaborative, multilocation, multigenerational, interest-driven, competency-based), and data considerations (e.g., multi-modal analytics, multi-domain, ethics, privacy). In this interactive symposium, leaders from these workshops will present posters with unfinished visions for a problematic future of learning with technology. AERA attendees will engage in discussing and prioritizing issues, challenges, and uncertainties for future research.

Session Summary

The Learning Sciences, learning technologies and challenges of equity are rapidly co-evolving. Students carry mobile devices with voice recognition, motion sensors, location awareness, and powerful cameras. Within 10 years, learners will experience AI learning agents, social robotics, tangible and embodied computing, and more (Sharples et al., 2016). Simultaneously, learning science theories are expanding to include embodied cognition, identity development, student agency, extended learning across time and place, and design principles (Roschelle et al., 2017). Equity and inclusion is becoming rapidly more problematic as we contend with issues of power, justice, privacy and security in an increasingly complex digital domain (Esmonde & Booker, 2016). Over the past year, the national center has organized a community process of discussions about these intersecting trends.

This session creates a space for informed, engaged discussion that to include AERA attendees. The space will be framed by posters from six workshops. Three posters highlight issues related to future learning environments: (a) social robotics (b) ubiquitous team learning and (c) learning across boundaries. Another three posters highlight research challenges: developing meaningful multimodal analytics, designing for inclusion and equity, and understanding adaptive learning across expansive settings. The posters will invoke a history that began with 11 independent NSF-funded scientific workshops (each with 20-60 participants), followed by a synergistic summit among workshop leaders (see Figure 1), and then a broadening conversation with 200 participants at an October 2019 conference. Through an interactive poster format, we will invite AERA attendees to join the conversation and the process of co-designing future research priorities.

The objectives for this session are:
1. Inform attendees about the themes, findings, and recommendations of recent scientific workshops,
2. Engage attendees in identifying key issues, challenges, dilemmas, and tensions
3. Collectively consider research priorities that are grounded in learning sciences theories, equitable for learners, and safe for individuals and society.

Please note that by August 31, 2019, all workshops will have produced a public report. Report copies will be available at each poster; the poster itself will highlight the main content, findings and recommendations.

The agenda will be:

- 6 mins: Open Chair introduces history, purpose, and process
- 9 mins: Each poster gives a 90 second introduction
- 35 mins: Attendees visit posters and engage with workshop leaders. Participants are invited to write stickies with issues or challenges they want to prioritize.
- 30 mins: Facilitator organizes posting of stickies and noticing emergent clusters, followed by open discussion priority issues
- 10 mins: Workshop leaders reflect on what they heard

The significance of this session illustrates that many voices must join the conversation to shape our collective understanding of the priorities that are most important to the future influences of learning sciences research with emerging technologies, especially with regard to equity issues. So that the conversation continues onwards, we will capture this AERA session and share key findings and recommendations publicly in an open-access report.

1. Sociable Robots: Prompting Children’s Agency

Two main purposes prompted the organization of this workshop: to track the status of research and development of sociable robots (i.e., embodied humanoid robots) for young children in both theory and technology, and to identify key areas on which the interested community needs to focus in the near future. Sixteen select scholars were invited from multidisciplinary fields of education and learning sciences, social robotics (Human/Robot Interaction), audio data processing (i.e., speech recognition and dialogue generation), and visual data processing (i.e., emotion detection through facial expressions, gestures, and bodily movements).

Among relevant findings, three topics are highlighted here. First, reports from empirical studies suggest that children’s engagement with sociable robots exceed expectations in that rich multimodal and multisensory interactions occur regularly. Especially notable were observations concerning children’s agency and personalization, such as spontaneous demonstrations and explanations of scientific ideas to a robot based on personal experience, expressions of friendship and affective relations, and the acceptance of a robot as an equal
partner in conversations. Second, scholars reported on-going efforts to improve analysis of different modalities of children’s behavior including speech, gestures, and bodily movements. Advances were also reported in detecting emotions through the analysis of facial expressions. These are promising developments that continue to lay the groundwork for developing sociable robots that are able to autonomously respond to children’s multimodal behavioral expressions. Third, what has emerged clearly from the workshop contributions is that, as of yet, no unified theory or model of child/robot interaction is in development, and that different researchers leverage different theoretical perspectives in a haphazardly way. Particularly, findings from developmental psychology or educational research have little influence on design and analysis of this fast-growing area of child/robot interaction (CRI).

Overall, workshop participants agreed that sociable robots are a powerful tool to trigger children’s earnest engagement in a large variety of educational activities. These include such activities that foster STEM learning, those that are designed to support children in developmental need, and those that seek to create equitable learning contexts for children who come from diverse backgrounds. Also promising is the affordance of a robot to instantiate children’s interest-driven activities. To be successful, it is crucial to design activities adroitly to embrace children’s divergent thinking and voluntary input while guiding them to achieve the intended learning goal. Some challenges remain. CRI technical development is moving quickly with little theoretical development or in-vivo empirical studies, likely to raise social and ethical questions. Substantial cross-cultural differences may exist in attitudes towards robot use among parents, teachers, and communities, increasing uncertainty of broader use.

Lastly the workshop participants recommended that the establishment of standing research communities at primary venues (e.g. AERA, ICLS) is strongly warranted to continually develop theoretical frameworks for child/robot interaction design and analysis. They were also vocal in highlighting the need for in-vivo studies and multimodal data collection and analysis.

2. Digitally-Mediated Team Learning

Purpose: During April 2019, a group of faculty, learning scientists, and industry partners assembled to discuss the state and the future of digitally-mediated team learning. The purpose of the proposed structured poster is to discuss the outcomes of the workshop, which includes the state of the field and future research and development. Digitally-Mediated Team Learning (DMTL) encompasses cooperative learning in digital classroom-based settings. We will identify DMTL, its guiding principles, and provide the outcomes of an NSF-supported workshop.

Perspectives: At the nexus of Team-Based Learning and Computer-Supported Collaborative Learning is DMTL. Within DMTL, teams work together in a digital classroom-based settings, where knowledge is co-constructed utilizing common resources. The focus of DMTL includes classroom-based STEM problem-solving, in real-time. DMTL leverages data analytics and the potential of machine learning to advance learning outcomes and scalability.
Methods and evidence: Education, government, and industry experts met together to discuss DMTL and its future capacity. Attendees self-selected an initial track where they had expertise, which included: tools, analytics, pedagogy, and inclusivity. Prior to the workshop, attendees wrote an abstract or position paper establishing their level of interest and expertise in the track. Google Docs supported the discussions that ensued in large and small groupings while participants contributed information. The resulting raw data collected was then edited by a group of attendees that volunteered to read and contribute to the resulting summary report. During the structured poster session, we will share highlights and future projections for DMTL.

Results: Recommendations for DMTL were divided into three categories: (a) immediate, (b) near-term, and (c) long-term. While over 50 recommendations were generated, two per category are highlighted herein:

Immediate 1: Increase research evidence on efficacy of DMTL across delivery modalities.
Immediate 2: Develop a glossary of DMTL-relevant terminology, methods, and metrics.
Near Term 1: Create reusable/adaptable DMTL activities that employ analytics for real-time cooperative learning.
Near Term 2: Create a Virtual Innovation Center showcasing high-impact DMTL practices.
Long Term 1: Develop new data science approaches exploring various team formations’ impact on learning outcomes.
Long Term 2: Apply and extend artificial intelligence within DMTL to personalize learning experiences.

Scientific or scholarly significance of the study or work: Aspects related to inclusive DMTL learning ecologies were identified and discussed. Participants concurred that existing learning technologies and data analytics could be harnessed in new ways to increase and broaden learner participation in STEM, the human factor cannot be ignored, and there remains a need to prepare instructors and students to reduce known and unknown biases to promote equitable learning (Wise, Vytasek, Hausknecht, & Zhao, 2016).

Researching the nexus of self-reported identity inventories, student perceptions’ of outcome expectations, learning analytics, machine learning, and psychosociological factors could provide needed insights. Current perspectives and future directions have indicated that DMTL would benefit from interdisciplinary investigations that included Learning Scientists, STEM Educators, Computer Scientists, and STEM Content Experts, repurposing current and developing new technologies, and investigating environments conducive to broadening and sustaining bias-free participation in STEM.

3. Crossing national, cultural, and economic boundaries through distributed, project-based STEAM collaboration
Distributed collaboration between individuals in the workplace is common. We look at distributed collaboration in different countries such as America and Africa. Work teams come in all varieties, and include members from different cultures, countries, economic backgrounds, or generations. Video- and tele-conference technologies enable shared virtual presence for synchronous collaboration and communication in the workplace. Virtual presence enables participants to cross geographic, cultural, generational and other boundaries. Such boundary crossing is a ubiquitous part of many work environments, and certainly integral to the worklife of most AERA participants.

This design and synthesis workshop envisions such boundary-crossing in next-generation and future learning environments for young people to become as abundant in daily routines as it is for many in the workforce. The two most salient differences are age (young person versus adult) and setting (workplace versus school or learning environment).

Extensive distributed collaboration between pre-college students remains relatively impractical in most school settings due to logistical, privacy, and technological limitations. Additionally, complex distributed collaborations do not currently have the driving force in classroom practice that characterizes the need for adults to collaborate in the global workplace. Yet each factor that limits such collaborations between young people in learning settings is manageable, and the inexorable expansion of social connections in global society will inevitably drive distributed teamwork in learning settings (Hamilton and Owens, 2018).

This workshop originated in selected exemplars of such collaborations, including an NSF-funded project involving STEM/STEAM digital makerspaces shared between students from multiple countries (Kenya, Finland, Iran, Brazil, Namibia, and the US). Results affirm that boundary-crossing collaboration between young people in learning settings is a worthy aspiration for future learning environments. Workshop participants routinely reported that heterogeneous (i.e. boundary-crossing) STEM problem-solving elicits sophisticated STEM learning and complex reasoning (e.g., Popov et al., 2014; Hamilton and Kallunki, in press). That is, diversity of participation in trust-rich contexts appears to stimulate diversity of applied reasoning. Equally important, virtual collaboration in STEM problem-solving that takes place in ways that lead students to cross boundaries routinely elicits complementary sentiments of curiosity, pleasure, and joy - both in learning and in helping others to learn - in addition to STEM competence formation.

Helping to shape future learning environments in ways that foster effective distributed cross-boundary collaboration has singular promise in a world where misunderstanding and mistrust flourish simply based on geographical differences or other differences that people perceive. The underlying premise of this line of research is not only to deepen STEM/STEAM learning, as large as that goal may be. This research seeks to convert shared projects and the need to help one another learn into the basis for young people defining their understanding of
the world around them, rather than defining those understandings based on differences or boundaries.

In service of this goal, the workshop sought to build theoretical clarity around constructs such as boundaries and boundary-crossing, the virtual presence and virtual migration at the heart of such collaboration, cultural competence in online settings, and boundary objects created in distributed collaboration.


Can multi-modal sensing technology change what “counts” in project-based learning environments? Consider makerspaces, where learners work, often collaboratively, through a combination of design and prototyping activities. These environments, and in particular the open-ended, collaborative activities that take place in them, pose unique challenges in comparison to more structured learning and performance environments as tasks are ill-defined, activities emergent, and criteria to evaluate the work unclear or contingent. Stated learning objectives for these spaces often include collaboration skills, emotional resilience, and dispositional shifts (Bergner, Abramovich, Worsley, & Chen, 2019), all of which are notoriously difficult to assess.

Sensing-based analyses of collaboration and learning processes aim to fill a gap between ethnographic studies, which preserve naturalistic features but are difficult to scale up and survey-based quantitative studies, which may interrupt natural flows. Multi-modal sensing technologies have begun to appear in specialized experimental classrooms and laboratory studies (e.g., Ochoa & Worsley, 2016; Chan, Ochoa, & Clarke, 2020). Developments in sensing technology and combined expertise from a range of socio-technical research fields continue to lower the barriers to studying such interactions in authentic learning and work environments.

Understanding collaborative processes in an instrumented learning space calls on convergent knowledge and methodology from learning sciences, psychology, computer science, and design fields. The working group brought together researchers working in focus areas of collaborative learning, enactive learning spaces (project-based learning, makerspaces, FabLabs, etc.), human dynamics, human-computer interaction, organizational studies, and multi-modal learning analytics. The working group engaged in a series of planning meetings via teleconference, with an in-person gathering in New York City. We explored affordances, constraints, and data infrastructure requirements for high-fidelity capture of performance, learning, and collaboration in active spaces. Moreover, we physically instrumented and collected data from a prototyping activity which we carried out at the NYU Tandon Makerspace. The makerspace activity simulated in-vivo data collection to explore the processes and methods of evidence identification which can be transferred to other sites.

The workshop helped to identify some key challenges and recommendations. First, it is important to note that instrumentation can be in competition with learning design. It is tempting
to try to “record everything” and make sense of it later, but a principled approach to evidence-centered design (Mislevy, Steinberg, & Almond, 2003) is called for. Otherwise 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.” A principled design approach may also require richer models (socio-techo-cognitive) of learning and behavior. Second, to open new windows into hard-to-measure constructs, instrumented learning spaces will benefit from collaboration between organizationists, educationists, and technologists. Researchers in organizational studies, for example, have explored the role of space in supporting collaboration and knowledge sharing (Fayard and Weeks, 2007; 2011). The physical design of makerspaces can tacitly communicate values or even gender bias. Qualitative studies have acknowledged the role of both the social construction of a space as well as its physical construction when considering how it shapes behavior.

5. Designing for Equity and Inclusion in Technology-rich Innovative Learning Spaces

This workshop examined ways of designing innovations in learning with inclusive principles at the core of three interrelated areas: 1. studio-based learning in makerspaces (Kafai & Peppler, 2010), 2. access, equity, and inclusion (Calabrese Barton, Tan, & Greenberg, 2017), and 3. digital/virtual learning opportunities (Litts, Halverson, & Bakker, 2016). Sixty educators, education researchers, education supporters, and non-profit organizations convened. Through cross-sector collaboration, participants synthesized key ideas and created action plans leading to actionable next steps.

Outcomes were nested within a framework of social and community change that shifted away from ready-made knowledge toward a process of critical, creative, and collaborative inquiry (Halverson & Sheridan, 2014). Discussions revealed that in equity-focused learning environments, learners construct their own understandings by enacting processes and pursuing inquiries of their own design. Learning and design needs to create mechanisms for interest-driven, peer supported, and relationship-based bi-directional expertise among users who come together for shared purposes. As a result, learning that involves making is connected to real world purposes and connected across communities (Calabrese Barton & Tan, 2018).

While workshop participants acknowledged the benefits of community-centered learning principles and practices as common foci, challenges and constraints were also brought forward (Davis, Schneider, & Blikstein, 2017). These constraints addressed a lack of consistency in capturing learning across populations using shared processes and techniques. In a dynamic system of ever-shifting practices, populations, and contexts, the tools needed to examine progress and track growth have yet to be developed. Tools for assessment must address system-level, individual-level, interaction-level, and longitudinal processes and outcomes.

Centering issues of equity and inclusion squarely in the center of our workshop introduced the discussion of several tensions. Participants acknowledged that much attention
has been paid to developing principles for equity, such as those developed by AccessCyberlearning -- an NSF-funded initiative that fosters synergistic relationships among researchers, technology developers, and instructors to promote more inclusive learning. However, many principles for equitable design are not widely referenced nor well-implemented in practice. As a result, additional work needs to address tangible ideas for initiating research-into-practice implementation around equity and inclusion in an ongoing way. Inclusion means more than access; it involves taking into consideration the background, culture, language, experiences, and perspectives of all learners and honoring all voices. In this vein, participants reiterated that technology cannot, and should not, be viewed as neutral, or a great equalizer (Caidi, Shankar, Dalbello, & Froehlich, 2005). Technologies introduce challenges and re-introduce inequities such as unequal power dynamics that can breakdown the equitable and accessible ideals of democracy.

As investments in technology continue to be made, we need to explore the realities and drawbacks for digitally-distributing learning within and beyond physical spaces and connecting virtual and face-to-face participants. Doing so isn’t as simple as introducing a digital platform or providing a network; it requires planning to sustain connectivity as a core practice to build collaboration and community.

6. Adaptive STEM Learning Environments Across Domains and Settings

Our workshop purpose was to construct needed new collaborations between the learning sciences, computer science, and assessment communities with a strong focus on learning that is NOT limited to a single setting or STEM subject -- instead expanding across time, across settings, and to related STEM subjects (NRC, 2014). We focused on three driving questions: (1) How can environments for integrated STEM learning bridge formal and informal learning for diverse learners? (2) What innovative research methods and modeling formalisms are needed to capture, characterize & support claims about effective learning across spans of time, settings, and subjects? (3) How can learning progressions be created to assess such expansive learning?

Participants shared key papers on relevant topics for a shared repository (such as Barron et al., 2014; Mislevy et al., 2012; Worsley et al., 2016), gave talks on a primary problem aligned to workshop goals, and shared elements of a vision of expansive learning. These were considered in cross-specialization group discussions, report outs, and collaborative writing processes, resulting in design principles and associated Learning Environment Vignettes.

Findings:

1. Rich examples exist bridging formal/informal and integrating STEM disciplines and/or links to work contexts
2. Interest-driven learning is a strong theme.
3. There is a need for longitudinal STEM learning data on interests, achievements, socio-emotional learning across domains and settings.
4. Knowledge mapping that articulates relationships between learning progressions across multiple domains is important.
5. Measurement of socio-emotional learning constructs related to achievement (self-efficacy, identity, mindsets) is weak.

Design Principles:
1. Figure-Ground Flip Principle: Make world the focus; incorporate telepresence, virtual labs.
2. Measurement Principle: Prioritize long-term performance or competence assessment with both SEL and knowledge components.
4. Learner Empowerment Principle: foster STEM learning agency and self-efficacy for equitable participation in learning opportunities.
5. Human-Virtual Agent Interaction Co-Evolution Principle: Virtual agents must adapt to humans, and learners will need to adapt to including agents.

Tensions emerged between (a) capturing/storing multimodal data longitudinally across settings for building comprehensive learner models and recommended learning activities for integrated learning outcomes, with (b) concerns of data privacy and risks of stereotyping due to labeling. Many problems are wrought by the inscrutability of AI models when they make recommendations for what/when/why a learner should be learning. How can our field avoid “algorithms of oppression”?

Research is needed to:
- Find ways to capture student interests (including by instrumenting environments), further defining the concept of multi-threaded learning progressions for integrated STEM, and conceptualizing adaptive learning as suggesting learning pathways that are longitudinal and co-constructed, not just playlist of fixed learning objects;
- Define constructs of socio-emotional learning, e.g., STEM Interest, Identity, engagement, self-efficacy, and develop instruments to measure them for integrative STEM learning over time;
- Identify and measure STEM cross-cutting competencies (e.g., Abstraction; Modeling; Spatial Reasoning; Algorithmic and Systems Thinking)
- Identify STEM learning interests for students/groups/classrooms and networked learning architecture which enables adaptive recommendations for learning pathways;
- Integrate virtual companions in human teaching & learning environments.
References


International Conference on Human-Robot Interaction: Vienna, Au. March 6-9, 2017


