Distributed Collaboration in STEM-Rich Project-Based Learning
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Workshop Outcomes
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How do we advance educational and socio-affective goals through distributed collaboration in STEM projects?

Abstract

This report discusses outcomes from a workshop focused on distributed collaboration of K16 STEM projects. The purpose of the workshop was to begin framing a research agenda to articulate both a) foundational research issues in distributed collaboration in STEM project-based learning, especially when student backgrounds differ significantly along national, cultural, economic, or linguistic dimensions; and b) important design principles for such distributed collaboration. This report also addresses potential applications that cut across both formal and informal STEM education contexts.

Keywords

Project-based learning; STEM; distributed collaboration

Introduction

The original impetus of the workshop was research into the interaction between variables associated with learning, culture, and collaboration when school-age students in after-school STEM clubs carried out digital makerspace projects by working with peers in clubs in other countries. Specific projects involved learners in North and South America, Africa, Asia, and Europe. Such multifaceted and international collaboration can only take place successfully through extensive planning and multilayered arrangements.

Investigators noted a compelling dynamic that transcended logistical considerations: The very fact that students were both so different from each other and so like each other (in terms, for example, of STEM interests) fueled a curiosity, appreciation, and desire to communicate and co-create that videoconferencing in particular seemed to intensify. This led to a conjecture that when students can collaborate over video with peers in other cultures from the safety of their own school or home settings, their collaboration can be richer than without video, and their intercultural competence has a greater opportunity to flourish.

Emerging cybertools enable high interactional bandwidth forms of distributed collaboration that extend significantly beyond those of the past. Distributed collaboration over the internet by school age students has been in practice for a quarter-century (Pea, et al., 1994). It is the relatively recent advent of reliable and high bandwidth video conferencing, other advances in communication and cloud technologies, along with the concurrent ascendance of the makerspace and social sharing movement that have reshaped the distributed collaboration landscape. It has done so in ways that merit reconsideration of ways to reach some of the most elusive goals of the national STEM education enterprise.
Workshop attendees

This workshop included a diverse and international collection of approximately 25 individuals*. Participants included prominent research methodologists, instructional practitioners and design specialists, learning scientists and technologists, a prominent education futurist, a university president widely published in areas essential to this topic, nationally known experts in computational thinking, and data scientists. Collectively, they represented education service and leadership from the US, Kenya, Brazil, Singapore, and Finland.

Three webinars (held in February, March, and April of 2019) helped set the stage for the workshop. The topics included Computational thinking and digital/media technology in learning; Personalized learning, shifting role of the teacher and the future of learning; and crossing regional, national, cultural, ethnic, economic boundaries in STEM project-based learning.

The workshop took place in May 2019 at Pepperdine University. The opening session involved a priming exercise that presented different current examples of boundary-crossing distributed collaboration. Then, each of the core team of invitees gave presentations, spurring lively discussion and a corpus of inputs for workshop products. The presentations and related materials from the workshop appear at: bit.ly/pepperdine-dcl-all-content-2019.

The topical areas and subsequent questions each expert was asked to address included:

- **Insights:** What new understandings do you have or formed on how boundary-crossing impacts learning?
- **Theoretical directions/frameworks:** What are existing frameworks that can be built on? How do we develop theoretical gravitas around boundary crossing? Who are the 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?

*Attendees listed in the Appendix.
Workshop structure

The workshop, which took place May 13-14, 2019, was one of a series synthesis and design meetings that the National Science Foundation (NSF) funded to focus on issues essential to future learning environments. NSF explicitly sought ideas for adaptable and distributed digital learning environments that could serve as a forum for active research and development studies in optimizing learning for groups and individuals.

Aspirations for these workshops align with efforts by many organizations in recent years to articulate shifts which must take place in education. The term “21st century skills” has sparked scrutiny globally on understanding and articulating the difference between what education systems prioritized in pre-digital era schooling, and what society needs now and in the future.

Scardamalia and Bereiter’s early articulation of knowledge building (KB) communities (e.g. Scardamalia & Bereiter, 1994) gave new language and a stable and still expanding theoretical framework to researchers navigating the convergence of discourse, learning, community, and communication technology. They recognized that society’s transition from pre-digital to digital eras created opportunities that obligated reconceptualizing school and knowledge formation. Influential work by the KB community and other researchers in computer-supported collaborative learning have led to well-known formulations for 21st century skills that include the 4Cs of collaboration, creativity, critical thinking, communication and numerous variations of these 4Cs (Dede, 2010). Each of these, especially collaboration, appears recurrently in different forms in current NSF proposal solicitations and other sponsored projects.

These developments have coincided with significantly greater appreciation of the mutually reinforcing nature of socio-affective and cognitive growth. Relatedly, the importance of help-giving as a prosocial disposition has been increasingly recognized as crucial to positive affect and healthy personality integration (Webb & Mastergeorge, 2003). It is central to the kinds of collaborative community competence envisioned by this workshop.

These themes add to an orientation around competence formation as an education goal. Competence includes and extends beyond academic knowledge, to the holistic exercise of interpersonal faculties, imagination, and determination. Additionally, the rise of social media has created previously unavailable opportunities for adolescents to create and communicate personal meaning.
These directions align closely with building learning communities that routinely include remote collaborators from different cultures, countries, or economic strata. These directions have become even more prominent, of course, with the coronavirus pandemic. At the time of the workshop, they helped to set the stage for the workshop’s effort to frame a usable research agenda to help articulate research issues and design principles in contemporary distributed collaboration.

Key issues

Any evolution of learning ecosystems can be interpreted through myriad conceptual or theoretical frameworks, and, in turn, contribute to theory testing that relates to those frameworks. The emphasis in this workshop on boundary-crossing collaboration adds an important dimension to these interpretations and contributes to the key terms below. Future research in this domain should clarify or refine use of the following terms, which arose in workshop conversations.

**STEM projects or challenges** refers to projects rich in STEM content which are designed to result in one or more discrete, physical, or digital artifacts. Artifacts can take a physical form, and can embody social cognition and obligate or spur intellectual growth (Peppler et al., 2016).

**Distributed collaboration** refers to teams geographically located in two or more venues working on tasks that produce shared digital or physical artifacts reflecting all partners, with internet-mediated communication.

**Boundary-crossing** refers to distributed collaboration involving team members who differ along dimensions of interest—in the workshop discussion, nationality and culture are two such boundaries.

**Virtual presence** refers to the perception that one is in a physical location by dint of being present in that location through communication technologies. Recurring literature contexts include immersive games, simulations and virtual reality, and telemedicine.
Interactional bandwidth refers to the magnitude of social and disciplinary content that can be expressed or perceived in a learning setting. The advent of reliable and no-cost or low-cost video communication is a crucial development for the transformative possibilities of boundary-crossing distributed collaboration.

Social trust, discussed below, refers to the belief that others will not, at worst, knowingly or willingly do you harm, and will, at best, act in your interests (adopted from the definition of the Europe Social Survey).

Social Trust

Workshop attendees repeatedly converged on building social trust as a crucial or transcendent factor or variance account in successful distributed collaboration, especially when participants differ by the country, culture, or economic stratum in which they live. In our country’s increasingly pluralistic society, and in a shrinking global society, boundary-crossing collaboration teams will likely become a common and normative practice.

The role of social trust in a nation’s institutions and society has gained increased recognition in recent years; its role in distributed collaboration settings has long been recognized but has had little theoretical or experimental specification, especially in more recent environments that allow virtual presence by video between school-aged participants.

Heterogeneous STEM problem-solving contexts

Heterogeneous 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. This corresponds to multiple theoretical frameworks on social cognition and negotiation of shared meaning or intersubjectivity (Stahl, 2016).

Computer-supported collaborative learning fosters both the engagement and reconciliation of multiple perspectives. In the same way that social trust can straddle being an individual trait and a socially owned trait, social cognition in collaborative problem-solving augments and transcends individual cognition to become a collectively shared process that is pervasive in daily life.
Virtual collaboration leads to satisfying learning interactions

Virtual collaboration, especially through videoconferencing, in STEM problem-solving that takes place in ways that lead students to cross new boundaries, routinely elicits complementary sentiments of curiosity, pleasure, satisfaction, and deep enjoyment in the interactions leading to learning and competence formation. The prosocial dynamics associated with it should be considered carefully.

Theories of playful learning (Kangas & Ruokamo, 2012) applied to distributed collaboration provide one relevant analytic framework for organizing or articulating these dynamics. They relate strongly to growing attention in the field to the mutually reinforcing nature of social, affective, and academic growth in such virtual collaboration. This includes multiliteracy competences, defined as skills to help students to understand culturally diverse forms of communication and to build their identity.

Interest-driven creator theory

Interest-driven creator theory (IDC) may prove an important aspect of driving collaborations envisioned as a routine aspect of distributed collaborative learning. IDC is an evolving learning design framework in computer-supported collaborative learning that prioritizes student interest in creating different types of artifacts (Chan et al., 2018).

An important 2018 foundational article on IDC, with twenty co-authors led by Tak-Kwai Chan and Chee-Kit Looi, offers IDC as "a theory of learning design for Asia in the twenty-first century." The theoretical connections that it draws, though, with multiple levels of articulation across the constructs of interest, creation, and habit, are not Asia-specific.

Self-determination theory

Self-determination theory provides a convenient set of constructs for emphasizing prosocial benefits of distributed collaboration in STEM project-based learning. The theory’s emphasis on autonomy, relatedness, and competence as essential building blocks to
nourishing personal well-being and social health correspond to the dynamics of forming project-based (e.g., makerspace) communities through distributed collaboration. Project-based learning is inherently oriented around creating artifacts and intrinsically addresses competence. Interacting with others in synchronous and asynchronous forms through a community structure intrinsically addresses relatedness. It emphasizes self-directed project definition and discourse scaffolding that explicitly recognizes and respects cultural differences and similarities, addressing autonomy.

Assessing or evaluating distributed collaboration
Tools for assessing or evaluating distributed collaboration in STEM projects must encompass not only the constructs of interest such as the 4Cs, engagement, intercultural competence, or academic growth in STEM competence, but the relationships between those constructs. Tracing relationships between constructs can furnish richer and more holistic views of how individuals and groups progress through distributed collaboration.

The workshop devoted time to elaboration of quantitative ethnography (Shaffer, 2017) as a methodological approach to using collaborative discourse to furnish statistically supported and finely-grained visualizations of group and individual progress in distributed collaboration.

Recommendations for future work
An underlying vision of this workshop is that internationally distributed collaboration should be recognized as a transformational opportunity that allows students to invent fresh ways to see and understand those who differ from them, and to align and reinforce cultural norms of listening and respect. The use of a shared activity system – in this case, distributed collaboration over STEM projects, can take the formative role in students’ lives of helping to shape or define how that students situate themselves with others who differ from them.
Our recommendations include testing linkages between cognitive, social, and affective dimensions of the high bandwidth STEM project-based distributed collaboration settings. Research in lower (non-video) bandwidth distributed collaboration settings and early research in higher bandwidth settings confirm that social connectivity has both positive affective and positive cognitive effects. These can be pursued through multiple avenues; the initial workshop proposal suggested, and the participants concurred, that ethnographic studies to articulate these connections are essential. They specifically agreed that the epistemic network analysis tool supporting quantitative ethnography could prove especially useful in this process.

This area is ripe for social policy research. The vision of using high bandwidth distributed collaboration in STEM projects as a tool not only for educational goals but for concurrent socialization and cross-cultural learning goals requires situating such projects in policy and curriculum contexts.

The degree to which schools or school-based informal settings make room for STEM distributed collaboration involving students partnering with peers in other jurisdictions will turn on such research and determinations of the tradeoffs those collaborations entail.

There is sufficient basis to explore the viability of such activities, but not yet enough evidence to confirm that existing designs are sufficient or that the resource tradeoffs merit beginning the transition to the more ubiquitous presence that workshop participants envision.

As the world experienced a global health pandemic in 2020, the efforts in boundary-crossing distributed collaboration are all the more timely. There is more interest to look at ways for students to have enriched interactions with each other as virtual exchanges in K16 learning becomes at first a necessary, but then a permanently sustained aspect of global society.

For further information about this workshop, our discussion, and complete citations, please read the full white paper.
References


**Resources**

International Community for Creative Content Creation (IC4) Project:  
[http://ic4.site](http://ic4.site)

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Appendix:

Workshop Participants:

Guadalupe Carmona (University of Texas, San Antonio), Shaundra Daily (Duke University, NC), Brendan Eagan (University of Wisconsin, Madison), Danielle Espino (Pepperdine University, CA), Lynn Frickey (Meteor Education, FL), Beatriz Galarza (University of Texas, San Antonio), Eric Hamilton (Pepperdine University, CA), Erik Huesca (Knowledge & Digital Culture Foundation, Mexico), Seung Bok Lee (Pepperdine University, CA), Chee-Kit Looi (National Institute of Education, Singapore), Ana Paula Luciano (Assessoria em Robótica Educacional Aplicada, Brazil), Arquimedes Luciano (Assessoria em Robótica Educacional Aplicada, Brazil), Rex Miller (Mindshift, TX), Jari Multisilta (Satakunta University of Applied Sciences, Finland), Marjaana Kangas (post-workshop) (Lapland University, Finland), Aileen M. Owens (South Fayette School District, PA), Vitaliy Popov (University of San Diego, CA), Heli Ruokamo (post-workshop) (Lapland University, Finland), David Williamson Shaffer (University of Wisconsin, Madison). Pepperdine University participants included: Lexi Aria, Natasha Brown, Denise Calhoun, Pamela Donnelly, Amanda Lee, Leonardo Minelli, Luiz Oliveira.