International Journal of Computer-Supported Collaborative Learning (2020) 15:373–382
https://doi.org/10.1007/s11412-020-09325-3

Finding a place for equity in CSCL: ambitious learning practices as a lever for sustained educational change

Suraj Uttamchandani[1] · Ayesha Bhimdiwala[1] · Cindy E. Hmelo-Silver[1]

Received: 12 February 2020 / Accepted: 7 July 2020 / Published online: 13 July 2020

> "I concede that the tangible impact of CSCL on educational practice is very small so far. But this suggests that we must realign our efforts, not abandon our very raison-d'être."
> - Wise and Schwarz 2017, p. 455

In their discussion of the future of CSCL, Wise and Schwarz (2017) point to a considerable tension regarding the role of CSCL research in educational change. Critiquing CSCL's engagement with educational change, they primarily understand change as a matter of scalability and sustainability. Their conciliator character points to design-based research, meta-analyses, research-practice partnerships, and longitudinal research as needed to further connect CSCL with the goal of educational change. In alignment with Hod et al.'s (2018) response to this provocation, we agree that educational change can and should be a central aspirational goal of the CSCL community in the coming decade. However, to the conciliator's list, we add that centering *equity* will promote research that that can make a difference. Recognizing that educational equity has multiple, and sometimes contradictory, meanings (Gutiérrez 2009; Nasir 2020; Uttamchandani 2018), we think about equity as a tool to attend to how historical social inequality affects the lived learning experiences of people, focusing not just on equitable *outcomes* but also *processes* of learning that empower learners to become authors of their own futures (Gutiérrez and Jurow 2016).

As we consider the fundamental goals of education, we therefore argue rather emphatically that CSCL should not give up on educational change. We recognize that globally, education is inequitable and not always successful for all students (Chzhen et al. 2018). We position education as a social good. Learning environments in general and CSCL environments in particular must therefore be responsive to the epistemic diversity of learners. Epistemic diversity refers to the different ways of knowing in a discipline "e.g., perspectives, meanings, practices, values—that are historically and culturally constituted" (Agarwal and Sengupta-Irving 2019, p. 351). We argue that educational equity can be a boundary object (Star 1989)

✉ Cindy E. Hmelo-Silver
chmelosi@indiana.edu

[1] Center for Research on Learning and Technology, School of Education, Indiana University, 201 N Rose Ave, Bloomington, IN 47405, USA

for supporting CSCL's sustained presence in conversations about educational change. This is a timely goal, particularly in light of widening inequality and the increasing need for global citizenship education (Politics of Learning Writing Collective 2017; UNESCO 2014). In particular, we believe that CSCL is well-positioned to support the implementation of ambitious learning practices for all learners, and that these practices can empower students, support shared meaning-making, and potentially disrupt social inequality.

We define *ambitious learning practices* as pedagogies that encourage collaboration, dialogue, and productive disciplinary engagement (Engle and Conant 2002). Such practices stand in contrast to other classroom pedagogies, such as rote learning, "drill-and-kill," and test-preparatory approaches that when deployed exclusively can curtail long-term learning and dehumanize students (e.g., Oakes 1992). These more dehumanizing approaches are often used with minoritized learners, including poor students, students of color, and/or students with disabilities (Duncan 2000; Swartz 2003).[1] Thus, the learning practices at hand are a core equity issue. Examples of ambitious learning practices include problem-, project-, and inquiry- based learning (Glazewski and Hmelo-Silver 2019; Savery 2015). We call these practices *ambitious* because we recognize that they require significant orchestration and careful approaches to personalization at the individual, small-group, and classroom levels.

These pedagogies require learning environments that support student agency as learners engage in complex collaborative exploration and investigation, which include scaffolds and supports for learners to be successful (Glazewski and Hmelo-Silver 2019; Calabrese Barton and Tan 2010). Student agency refers to ownership and authority for making decisions about learning, thinking, and problem solving (Engle and Conant 2002). We see agency as linked to identity development and empowerment defined broadly, where students can take on and take up disciplinary identities rather than be rejected by them (Bell et al. 2017). As Calabrese Barton and Tan (2010) illustrate, from a sociopolitical perspective, learning is about recreating "practices in socially and culturally situated ways that confer on one more (or less) agency with which to participate across communities" (p. 190–191). Given that CSCL environments—such as those that include adaptive collaborative learning support (ACLS), teacher dashboards, and automated feedback from learning analytics—offer potential for feedback, scaffolds, and classroom orchestration that are localized and responsive, they may be well-suited to support learning defined in this way (Wang et al. 2011; Tegos et al. 2016; Dillenbourg et al. 2018; Gerard et al. 2019; Tissenbaum and Slotta 2019; van Leeuwen et al. 2019).

Shared meaning making is critical for ambitious learning practices. It refers to the construction of joint understanding and common ground (Suthers 2006; Sfard and Cobb 2014). This is an area of strength in CSCL research. For example, Roschelle's (1992) foundational study of convergent conceptual change highlighted the way that collaboration and intersubjectivity could support the learning of complex disciplinary concepts. However, collaborative environments do not simply seek to simply support students in acquiring robust content

[1] We use the term "minoritized" to refer to people who are marginalized by systemic and long-standing inequities. When discussing equity, word choice matters and shifts over time. Following Paris (2012) and Harper (2012), we prefer "minoritized" to "minorities" to highlight that it is harmful *systems,* rather than the *individuals* those systems disenfranchise, that are to blame for inequitable circumstances. Furthermore, in various global contexts, this term is meant to signify a wide range of historical and longstanding inequities (e.g., caste-based discrimination), although we encourage naming these specific oppressions when they can be clearly demarcated.

knowledge; rather, they also aim to foster more dialogical forms of learning (Bakhtin 1981; Resnick et al. 2015). As Stahl et al. (2014) argue, shared meaning making, especially through and for dialogue and group cognition, is the crux of CSCL scholarship.

Ambitious learning practices are fundamentally political. To theorize the role of education in disrupting social inequality, we draw on recent conversations in the learning sciences around political, power-laden, and ethical dimensions of learning processes (Esmonde and Booker 2017; Politics of Learning Writing Collective 2017; Philip et al. 2018; Uttamchandani 2018). This sociopolitical turn has pointed to questions like: How does learning contribute to a more equitable society? What are the political dimensions of a learning ecology, including who is learning, why is learning taking place, and what are the ethical values being reflected in this learning (Bang and Vossoughi 2016; Biesta 2013; Freire 1972; Taylor 2018)? How do social inequities, such as racism and anti-Blackness, manifest in learning environments, and how can we design to disrupt them? When and how does learning support culturally-responsive and culturally-sustaining ways of knowing, especially for minoritized learners (Ladson-Billings 1995; Paris 2012)? Although there are few relevant studies in CSCL in this regard, we note that some have begun to explore issues at the intersection of such political concerns and CSCL (e.g., Ramey and Stevens 2019; Rummel et al. 2016; Tchounikine 2019). Issues related to equity have become increasingly prominent in the learning sciences broadly and offer productive new ways to think about the relations among equity and collaboration, data, and technology (e.g., Esmonde 2009; Philip et al. 2016; Reinholz and Shah 2018).

In sum, then, ambitious learning practices support individual agency, group dialogue, and the disruption of social inequality. We see value in thinking across these related aspects of equity in education because we believe at their intersection is the most powerful point of resonance for the CSCL community to join conversations about educational change. We argue that when educational change centers equity by focusing on learner agency, shared meaning making, and the disruption of social inequalities, CSCL's strengths have the potential for unique and useful contributions to supporting equitable educational change.

There are several tensions as CSCL moves forward to focus on equitable educational change through the uptake of ambitious learning practices. For one, the effective use of CSCL designs tend to require a change in social practices, which comes with unique challenges across levels (Hakkarainen 2009). Social practices in classrooms are embedded in both school cultures and broader social and cultural norms (Zhang 2013). Even when technologies are designed for such change, there is no guarantee that these changes will be taken up productively (van Aalst 2009). However, there are several important elements of CSCL that are known to potentially increase the likelihood of CSCL practices being appropriated in effective ways (Jeong and Hmelo-Silver 2016). These include having a meaningful joint task, communicating, having ways to share resources, and having support for engaging in productive collaborative processes and regulation. Finally, there is a tension between viewing technology as compromising learner agency versus viewing technology as supporting new forms of learner agency (Wise and Schwarz 2017). For the CSCL community to effectively contribute to widespread educational change, we must consider how technologies and innovations can be adapted to be productive, responsive, and appropriate for a wide variety of contexts and their associated pedagogical practices. To contextualize our discussion, we next build on discussions from a series of NSF-sponsored workshops to explore how adaptive collaborative support (as an example of a CSCL innovation) may promote or hinder work towards equitable educational change.

Structure and agency: a test case for the use of an educational change lens on instruments in CSCL

As we consider Adaptive Collaborative Learning Support (ACLS) as an example of CSCL innovation, we also need to consider what happens when we try to understand the role of such an innovation in supporting ambitious learning practices. Although ACLS can offer lots of structure, central to ambitious learning practices is the goal of empowering students to exercise agency within and over their own learning. As Wise and Schwarz (2017) discussed in detail in their second provocation, the tension between providing structure and supporting student agency is a central one in CSCL (see also Rummel et al. 2016). Specifically, the structure that educational technology can offer to support learning may come at the expense of offering learners more opportunities to make choices and ask questions as they learn. Importantly, we therefore view the issue of structure and agency as centrally being about *power*: what kinds of structures support agency and empower learners, rather than diminishing agency and/or disempowering learners?

As discussed above, student agency tends to center learners' ability to take ownership of, make choices about, and hold a larger authority over their own learning (see Calabrese Barton and Tan 2010; Engle and Conant 2002; Tchounikine 2019). As Louie (2020) recently pointed out, it is possible to embrace student agency without disrupting underlying (often deficit) perspectives of who students are and what they are capable of. With this in mind, we take up a critical perspective on student agency that treats the disruption of educational and larger social inequality as a central concern in promoting student agency. Such an approach understands and position students as cultural-historical actors (agents), rather than the passive recipients of education (Freire 1972; Vossoughi and Gutiérrez 2017). We also understand learner agency as including students' ability to question knowledge, including how that knowledge was generated and what purposes it has been and might be used for. Therefore, when we describe a tension between structure and agency, we refer to agency in its politicized, power-laden connotation.

Given this tension around structure and agency, we turn to ACLS as a prototypical example that offers an opportunity to explore the role of CSCL innovations generally in fostering ambitious learning practices. Indeed, there is evidence that ACLS can support learning disciplinary content (e.g., Baghaei et al. 2007; Olsen et al. 2019; Tegos et al. 2016; Rau et al. 2017; Walker et al. 2011; Wang et al. 2011). Further, advancements in learning analytics and AI in Education have provided new opportunities to support teachers with individual, group, and classroom-level recommendations and predictions to improve teaching and learning in CSCL environments (e.g., Dillenbourg et al. 2018; Gerard et al. 2019; Tissenbaum and Slotta 2019; van Leeuwen 2015; van Leeuwen et al. 2019). Nonetheless, the introduction of ACLS and collaborative learning analytics into classrooms are not themselves ambitious learning practices. Rummel et al. (2016) imagine a dystopian scenario for learning in a chemistry class where students (and teachers) have no way to override their school's ACLS technology, students are paired with frustrating partners because such pairs are marked by the ACLS as supporting "constructive conflict," and predictive mechanisms can write off a student's potential (e.g., by demarcating one as a "poor collaborator"). By contrast, in their utopian scenario, the teacher and the ACLS technology confer on next steps and the ACLS orients to the students in a more human way (e.g., by encouraging them to take a break as they feel frustrated). The similarity, however, is the content of each lesson: standard chemistry. We argue that a real concern by CSCL with issues of disciplinary agency must attend more deeply

to questions about the *content* of learning (i.e., disciplinary ideas and practices) and how that content is situated in meaningful contexts. CSCL has long known that learning is especially productive when students engage in real-world problems, problems that are of personal meaning, or open problems in a discipline (Hmelo-Silver 2004; Papert 1980). For example, in a science class this could be sustained engagement with a science-based simulation (e.g., *Wallcology;* Slotta et al. 2018), in which scripted grouping and activity sequences support students in enculturating into a scientific community of practice. Zhang et al. (2018) go further in considering how students can take the lead in co-constructing their objects of inquiry as well as the inquiry cycles in which they choose to engage in. Although CSCL has had success in designing these environments, they thus far have tended to require experienced facilitators and sustained researcher involvement, a key challenge to their scaling out equitably.

Another barrier to the adoption of learning analytics and ACLS in ways that disrupt social inequality is how cultural and contextual factors are addressed during the design, development, and implementation of such systems (Wise and Schwarz 2017). To a limited degree, it is possible to build some awareness of demographic factors into these systems and to ameliorate systematic biases through participatory design (e.g., Ahn et al. 2019; Holstein et al. 2018). However, the evidence of inequity, bias, and racism in commercial technology systems (e.g., Benjamin 2019) suggests that cultural and contextually responsive systems at scale will require significantly more sustained attention to avoid "technological redlining" (Noble 2018), that is, the use of data to enact racial and racist profiling. With this in mind, it is important to make sense of how students' backgrounds and heterogenous ways of engagement are best engaged responsively by the CSCL technology, the teacher, and at the intersection of both (i.e., teacher-AI co-orchestration). This aligns well with Wise and Schwarz's provocative view of the teacher "as a collaborative engineer with analytics or adaptive system as an aid" (p. 447).

Although these ambitious learning practices reposition students as problem solvers rather than recipients of knowledge, they pose significant problems for adaptive support. For example, it is much more difficult in such environments for ACLS to take on the role of "intelligent tutor," able to understand best pathways through known-answer problems and guide students to and through such pathways. Thus, we conclude that such constraining is not the most productive use of ACLS. Instead, we imagine that adaptive support can focus on collaborative practices. In this way, even when agnostic to content, support could help students that the system detects as frustrated by prompting with metacognitive questions or collaborative learning strategies. Based on what such systems detect, they could prompt teachers to visit groups that appear to coordinate poorly or are especially enthusiastic (e.g., Alavi and Dillenbourg 2012; Schwarz et al. 2018; Prieto et al. 2016). ACLS cannot in and of itself create an exciting experience or substitute for a teacher's professional insights, but it can help support the high-quality collaborative engagement that may be necessary for participating in complex disciplinary practices and a long-term trajectory of enculturation into a community of practice.

A community of practice can support equitable education through joint attention to deep conceptual learning, identity development, and collaboration (Eberle 2018). Taking a community of practice perspective is not however sufficient to support equitable educational change. Ambitious learning practices seek to support students' agency through robust content, but must go beyond this by fostering more dialogical forms of learning and carefully attuning to the ethical dimensions of the content being discussed. From a critical Freirean perspective, "Simply replacing the *content* of teaching (from hegemonic to counter-hegemonic ideas) does not unsettle the social and intellectual relations that sustain an unequal society" (Vossoughi

and Gutiérrez 2017, p. 141). While we can imagine ACLS playing the role of an "other" in supporting dialogue and agency, we are wary of a "critical" classroom in which learners talk only to machines throughout the day (Rummel et al. 2016). The goals of ACLS are not to be prescriptive, but rather to be empowering for learners and to create the conditions in which (1) students have agency for their own learning and (2) teachers can provide targeted and synergistic supports for individual and collaborative activity (Fischer et al. 2013; Tabak 2004) Additionally, there are significant technological barriers to creating ACLS that can respond to the wider range of comments students might make in dialogical learning environments, a challenge that the CSCL community can take up through co-designing with teachers and learners. Moving forward, the CSCL community must contend with how to design, develop, and evaluate the use of ACLS for environments where open-ended inquiry or ill-structured problems/projects and dialogical forms of learning are valued (e.g., Blikstein and Worsley 2016; Olsen et al. 2015; Evans et al. 2019).

ACLS has immense potential for supporting engagement with disciplinary content, practices, and identification of students as a members (or potential members) of a community of practice. Given ACLS's ability to support teachers, it might also be especially transformative in under-resourced classrooms. Therefore, CSCL should not give up on educational change but instead consider how ACLS (and other CSCL innovations) can increase access to learning environments that support ambitious learning practices. Importantly, this means that a critical conception of educational equitable change cannot be an afterthought to the innovation of technology, but rather something considered throughout a project's development.

Some closing questions about CSCL and educational change

In this squib, we tried to remain brief as we outlined several dimensions that to us must be considered together in support of equitable educational change. We used the notion of ambitious learning practices – those that promote productive disciplinary engagement, collaboration, and dialogue – as a place where CSCL can offer a strong contribution towards equitable educational change. Importantly, ambitious learning practices in particular and equitable educational change in general must be understood as fundamentally political, and cannot be brought about without attending to the political contexts of our work. While this poses new challenges, we think the CSCL community should rise to these challenges. We stress this because we see immense danger in educational change that centers scalability and sustainability without foregrounding equity. As we argue, adding an equity "lever" can reanimate the field's initial commitment to such change and offer a productive way to ensure that CSCL insights, technologies, and pedagogies are considered in conversations about educational change. Although this equity lever has been mostly absent from CSCL conversations, it holds promise for sustaining CSCL's commitment to widespread educational improvement.

Given that this is our (i.e., the authors') first entry into the CSCL equity space, we close with some open questions that should be explored in the coming years:

- How do we provide structure for agency? Who helps provide the structures (and how do these promote or inhibit equity)? In other words, where is the optimal balance of structure and agency that supports equitable and socially just educational opportunities?

- We view relationships and shared meaning making, and not necessarily technology, as what scales out when equity is centered. To support equitable and productive mentorship for all, when and how does technology in classrooms assist teachers in scaling up/scaling out meaningful relationships and interactions with students?
- CSCL deals with classroom ecologies. Where in the complex system of a students' journey through education should CSCL researchers focus on to make the most sustained, productive, and equitable impact on students' learning and well-being? We conjecture that this will be different for different research teams: for some, it will be working closely with particular teachers in a deep way, and for others it could be focusing on systems, districts, curricula, or commercial technology. As Hod et al. (2018) have discussed, research-practice partnerships can be an important crucible for such research.
- As we increasingly produce technologies for adaptive support and collaborative learning analytics that respond to learners' inputs, who owns, and who should own, the data that students produce? How can researchers ensure they are not reinscribing the kinds of surveillance technologies that continually seem to benefit majoritized learners while further disciplining minoritized youth and specifically youth of color (Noble 2018)?

We conclude with a call for CSCL to join the conversation on equitable educational change. Although some might argue that those discussions are beyond the scope of our community's research endeavors, we disagree. One of the strengths of the CSCL community is that it is interdisciplinary and visions of what is possible in technology-mediated learning environments can also spark new visions of how equitable educational environments could come to be.

Acknowledgements This research was funded by the National Science Foundation under grant DGE #1547731 to the third author. The opinions, findings, and conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

Alavi, H. S., & Dillenbourg, P. (2012). An ambient awareness tool for supporting supervised collaborative problem solving. *IEEE Transactions on Learning Technologies, 5*(3), 264-274.

Agarwal, P., & Sengupta-Irving, T. (2019). Integrating power to advance the study of connective and productive disciplinary engagement in mathematics and science. *Cognition and Instruction, 37*(3), 349–366.

Ahn, J., Campos, F., Hays, M., & DiGiacomo, D. (2019). Designing in context: Reaching beyond usability in learning analytics dashboard design. *Journal of Learning Analytics, 6*(2), 70–85.

Baghaei, N., Mitrovic, A., & Irwin, W. (2007). Supporting collaborative learning and problem-solving in a constraint-based CSCL environment for UML class diagrams. *International Journal of Computer-Supported Collaborative Learning, 2*(2), 159–190. https://doi.org/10.1007/s11412-007-9018-0.

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays*. Austin: University of Texas Press.

Bang, M., & Vossoughi, S. (Eds.). (2016). Participatory design research and educational justice: Studying learning and relations within social change making [Special issue]. *Cognition and Instruction, 34*(3), 173–193.

Bell, P., Van Horne, K., & Cheng, B. H. (Eds.). (2017). Designing learning environments for equitable disciplinary identification [Special issue]. *Journal of the Learning Sciences, 26*(3), 367–375.

Benjamin, R. (2019). *Race after technology: Abolitionist tools for the new jim code*. John Wiley and Sons.

Biesta, G. (2013). Interrupting the politics of learning. *Power and Education, 5*(1), 4–15.

Blikstein, P., & Worsley, M. (2016). Multimodal learning analytics and education data mining: Using computational technologies to measure complex learning tasks. *Journal of Learning Analytics, 3*(2), 220–238.

Calabrese Barton, A., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences, 19*(2), 187–229.

Chzhen, Y., Gromada, A., Rees, G., Cuesta, J., & Bruckauf, Z. (2018). *An unfair start: Inequality in children's education in rich countries*, *Innocenti Report Card no. 15*. Florenc: UNICEF Office of Research.

Dillenbourg, P., Prieto, L. P., and Olsen, J. K. (2018). Classroom orchestration. In *International Handbook of the Learning Sciences* (pp. 180-190). Routledge.

Duncan, G. A. (2000). Urban pedagogies and the celling of adolescents of color, *Social Justice., 27*(3 (81), 29–42.

Eberle, J. (2018). Apprenticeship learning. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International handbook of the learning sciences* (pp. 44-53). New York: Routledge.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399–483.

Esmonde, I. (2009). Mathematics learning in groups: Analyzing equity in two cooperative activity structures. *The Journal of the Learning Sciences, 18*(2), 247–284.

Esmonde, I., & Booker, A. N. (2017). *Power and privilege in the learning sciences; critical and sociocultural theories of learning*. New York, NY: Routledge.

Evans, A., Davis, K., & Wobbrock, J. (2019). Adaptive support for collaboration on tabletop computers. In K. Lund, G. P. Niccolai, E. Lavoué, C. E. Hmelo-Silver, G. Gweon, & M. Baker (Eds.), *A wide Lens: Combining embodied, enactive, extended, and embedded learning in collaborative settings, Proceedings of 13th International Conference on Computer Supported Collaborative Learning (CSCL) 2019* (Vol. 1, pp. 176–183). Lyon, France: International Society of the Learning Sciences.

Fischer, F., Kollar, I., Weinberger, A., Stegmann, K., Wecker, C., & Zottmann, J. (2013). Collaboration scripts in computer-supported collaborative learning. In C. E. Hmelo-Silver, C. A. Chinn, C. K. K. Chan, & A. M. O'Donnell (Eds.), *International handbook of collaborative learning* (pp. 403–419). New York: Routledge.

Freire, P. (1972). *Pedagogy of the oppressed* (M. B. Ramos, Trans. New York, NY: Herder and Herder.

Gerard, L., Kidron, A., & Linn, M. C. (2019). Guiding collaborative revision of science explanations. *International Journal of Computer-Supported Collaborative Learning, 14*(3), 291–324.

Glazewski, K. D., & Hmelo-Silver, C. E. (2019). Scaffolding and supporting use of information for ambitious learning practices. *Information and Learning Sciences, 120*(1/2), 39–58.

Gutiérrez, R. (2009). Embracing the inherent tensions in teaching mathematics from an equity stance. *Democracy and Education, 18*(3), 9–16.

Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *Journal of the Learning Sciences, 25*(4), 565–598.

Hakkarainen, K. (2009). A knowledge-practice perspective on technology-mediated learning. *International Journal of Computer-Supported Collaborative Learning, 4*(2), 213–231.

Harper, S. R. (2012). Race without racism: How higher education researchers minimize racist institutional norms. *The Review of Higher Education, 36*(1), 9–29.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*, 235–266.

Hod, Y., Sagy, O., Kali, Y., & Taking Citizen Science to School. (2018). The opportunities of networks of research-practice partnerships and why CSCL should not give up on large-scale educational change. *International Journal of Computer Supported Collaborative Learning, 13*(4), 457–466.

Holstein, K., McLaren, B. M., & Aleven, V. (2018). *Student learning benefits of a mixed-reality teacher awareness tool in AI-enhanced classrooms*, *In Proceedings of the 19th International Conference on Artificial Intelligence in Education (AIED 2018). (pp. 154–168)*. Cham: Springer.

Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of CSCL technology: How can technology support collaborative learning. *Educational Psychologist, 51*, 247–265.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465-491.

Louie, N. (2020). Agency discourse and the reproduction of hierarchy in mathematics instruction. *Cognition and Instruction, 38*(1), 1-26.

Nasir, N. I. S. (2020). Teaching for equity: Where developmental needs meet racialized structures. *Applied Developmental Science, 24*(2), 146–150.

Noble, S. U. (2018). *Algorithms of oppression: How search engines reinforce racism*. New York: New York University Press.

Oakes, J. (1992). Can tracking research inform practice? Technical, normative, and political considerations. *Educational Researcher, 21*(4), 12–21.

Olsen, J.K., Aleven, V., and Rummel, N. (2015). Predicting student performance in a collaborative learning environment. In *Proceedings of the 8th International Conference on Educational Data Mining*. (pp. 211-217).

Olsen, J. K., Rummel, N., & Aleven, V. (2019). It is not either or: An initial investigation into combining collaborative and individual learning using an ITS. *International Journal of Computer-Supported Collaborative Learning, 14*(3), 353–381. https://doi.org/10.1007/s11412-019-09307-0.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Inc: Basic Books.

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher, 41*(3), 93–97.

Philip, T. M., Olivares-Pasillas, M. C., & Rocha, J. (2016). Becoming racially literate about data and data-literate about race: Data visualizations in the classroom as a site of racial-ideological micro-contestations. *Cognition and Instruction, 34*(4), 361–388.

Philip, T. M., Bang, M., & Jackson, K. (2018). Articulating the "how," the "for what," the "for whom," and the "with whom" in concert: A call to broaden the benchmarks of our scholarship. *Cognition and Instruction, 36*(2), 83–88.

Politics of Learning Writing Collective. (2017). The learning sciences in a new era of US nationalism. *Cognition and Instruction, 35*(2), 91–102.

Prieto, L. P., Sharma, K., Dillenbourg, P., and Jesús, M. (2016). Teaching analytics: Towards automatic extraction of orchestration graphs using wearable sensors. In *Proceedings Of The Sixth International Conference On Learning Analytics and Knowledge* (pp. 148-157).

Ramey, K. and Stevens, R. (2019). Girls as experts, helpers, organizers, and leaders: Designing for Equitable Access and participation in CSCL environments. In Lund, K., Niccolai, G. P., Lavoué, E., Gweon, C. H., and Baker, M. (Eds.), *A wide lens: combining embodied, enactive, extended, and embedded learning in collaborative settings, Proceedings of 13th International Conference on Computer Supported Collaborative Learning (CSCL) 2019, Volume 1 (pp. 368–375).* Lyon, France: International Society of the Learning Sciences.

Rau, M. A., Bowman, H. E., & Moore, J. W. (2017). An adaptive collaboration script for learning with multiple visual representations in chemistry. *Computers and Education, 109*, 38–55.

Reinholz, D. L., & Shah, N. (2018). Equity analytics: A methodological approach for quantifying participation patterns in mathematics classroom discourse. *Journal for Research in Mathematics Education, 49*(2), 140–177.

Resnick, L. B., Asterhan, C. A., & Clarke, S. N. (2015). *Socializing intelligence through academic talk and dialogue*. Washington, DC: American Educational Research Association.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *The Journal of the Learning Sciences, 2*(3), 235–276.

Rummel, N., Walker, E., & Aleven, V. (2016). Different futures of adaptive collaborative learning support. *International Journal of Artificial Intelligence in Education, 26*(2), 784–795.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. A. Ertmer (Eds.), *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. barrows* (pp. 5–15). Lafayette: Purdue University Press.

Schwarz, B. B., Prusak, N., Swidan, O., Livny, A., Gal, K., & Segal, A. (2018). Orchestrating the emergence of conceptual learning: A case study in a geometry class. *International Journal of Computer-Supported Collaborative Learning, 13*(2), 189–211.

Sfard, A., & Cobb, P. (2014). Research in mathematics education: What can it teach us about human learning? In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences (pp. 545–563)*. Cambridge University Press.

Slotta, J. D., Quintana, R. M., & Moher, T. (2018). Collective inquiry in communities of learners. In F. Fischer, C. Hmelo-Silver, S. Goldman, & P. Reimann (Eds.), *International handbook of the learning sciences*. New York: Routledge.

Stahl, G., Koschmann, T., & Suthers, D. (2014). Computer-supported collaborative learning. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences (pp. 479–500)*. Cambridge University Press.

Star, S. L. (1989). The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. In L. Gasser & M. Huhns (Eds.), *Distributed artificial intelligence* (pp. 37–54). San Mateo, CA: Morgan Kaufmann.

Suthers, D. D. (2006). Technology affordances for intersubjective meaning making: A research agenda for CSCL. *International Journal of Computer-Supported Collaborative Learning, 1*(3), 315–337.

Swartz, E. (2003). Teaching white preservice teachers: Pedagogy for change. *Urban Education, 38*(3), 255–278.

Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences, 13*, 305–336.

Taylor, K. H. (2018). The role of public education in place-re making: From a retrospective walk through my hometown to a call to action. *Cognition and Instruction, 36*(3), 188–198.

Tchounikine, P. (2019). Learners' agency and CSCL technologies: Towards an emancipatory perspective. *International Journal of Computer-Supported Collaborative Learning, 14*(2), 237–250.

Tegos, S., Demetriadis, S., Papadopoulos, P. M., & Weinberger, A. (2016). Conversational agents for academically productive talk: A comparison of directed and undirected agent interventions. *International Journal of Computer-Supported Collaborative Learning, 11*(4), 417–440.

Tissenbaum, M., & Slotta, J. (2019). Supporting classroom orchestration with real-time feedback: A role for teacher dashboards and real-time agents. *International Journal of Computer-Supported Collaborative Learning, 14*(3), 325–351.

UNESCO. (2014). *Global citizenship education: Preparing learners for the challenges of the twenty-first century*. Paris: Unesco. Retrieved from http://unesdoc.unesco.org/images/0022/002277/227729E.pdf.

Uttamchandani, S. (2018). Equity in the learning sciences: Recent themes and pathways. In J. Kay & R. Luckin (Eds.), *International conference of the learning sciences (ICLS) 2018, volume 1* (pp. 480–487). London, UK: International Society of the Learning Sciences.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning, 4*(3), 259–287.

van Leeuwen, A. (2015). Learning analytics to support teachers during synchronous CSCL: Balancing between overview and overload. *Journal of learning Analytics, 2*(2), 138–162.

van Leeuwen, A., Rummel, N., & van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning, 14*(3), 261–289.

Vossoughi, S., & Gutiérrez, K. D. (2017). Critical pedagogy and sociocultural theories. In I. Esmonde & A. N. Booker (Eds.), *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. New York, NY: Routledge.

Walker, E., Rummel, N., & Koedinger, K. R. (2011). Designing automated adaptive support to improve student helping behaviors in a peer tutoring activity. *International Journal of Computer-Supported Collaborative Learning, 6*(2), 279–306.

Wang, H. C., Rosé, C. P., & Chang, C. Y. (2011). Agent-based dynamic support for learning from collaborative brainstorming in scientific inquiry. *International Journal of Computer-Supported Collaborative Learning, 6*(3), 371–395.

Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning, 12*(4), 423–467.

Zhang, J. (2013). Collaboration, technology, and culture. In C. E. Hmelo-Silver, C. A. Chinn, C. K. K. Chan, & A. M. O'Donnell (Eds.), *International handbook of collaborative learning* (pp. 495–508). Philadelphia: Taylor and Francis.

Zhang, J., Tao, D., Chen, M. H., Sun, Y., Judson, D., & Naqvi, S. (2018). Co-organizing the collective journey of inquiry with idea thread mapper. *Journal of the Learning Sciences, 27*(3), 390–430.