

Unpacking 'Signs of Learning' in Complex Social Environments: Desettling Neoliberal Market-Driven Educational Methodologies, Epistemologies and Recognitions of Learning

Jennifer Adams, University of Calgary, jdadams215@gmail.com
Sylvie Barma, Laval University, sylvie.barma@fse.ulaval.ca
Marie-Caroline Vincent, Laval University, marie-caroline.vincent.1@ulaval.ca
Samantha Voyer, Laval University, Samantha.voyer.1@ulaval.ca
Jrène Rahm, Université de Montréal, Canada, jrene.rahm@umontreal.ca
Ferdous Touioui, Université de Montréal, Canada, ferdous.touioui@umontreal.ca
Pratim Sengupta, University of Calgary, Pratim.sengupta@ucalgary.ca
Marie-Claire Shanahan, University of Calgary, mcshanah@ucalgary.ca
Stephanie Hladik, University of Calgary, skhladik@ucalgary.ca
Dylan Paré, University of Calgary, dylan.pare@ucalgary.ca
Rachel Chaffee, American Museum of Natural History, rchaffee@amnh.org
April Luehmann, University of Rochester, april.luehmann@rochester.edu
Angela Calabrese Barton, Michigan State University, acb@msu.edu
Day Greenberg, Michigan State University, green106@msu.edu
Jessica Thompson, University of Washington, jjthomps@uw.edu
Sara Haganah, Boise State University, sarahagenah@boisestate.edu
Kevin O'Connor (discussant), University of Colorado, kevin.oconnor@colorado.edu

Abstract: This structured poster session examines the design and study of meaning making in and across multimodal contexts, exploring how recognition of new signs of learning, in new ways, might enter into the reconfiguration of educational practices and institutions. We expand on recent work in the learning sciences that challenges prevailing power structures and the ways that they are produced by existing ways of recognizing learning. The presentations build on the work of sociocultural and semiotic theories to challenge current neoliberal ideals about what counts as knowing, learning, and becoming, as well as who can come to know.

Introduction

Contemporary educational institutions are, as Gunther Kress (2013) has noted, in an unsettled state brought about by broken linkages among school, society, and economy. “The social,” Kress argues, “is marked by multiplicity, diversity, fragmentation, fluidity, provisionality, by far-reaching changes in distributions and assignation of power, which affect the agency and the potentials of individuals” (2013, p. 120). This opens up a need for reconsidering learning, in particular for understanding how recognizing new “signs of learning” might enter into the reconfiguration of educational practices and institutions. The Learning Sciences (LS) have of course for some time been engaged in this project. Like Kress, some in LS have called for a move beyond understanding learning research as an “administrative science” (Stevens, 2010) that identifies learning through the use of “metrics of achievement” (Kress, 2013) with origins and interests exogenous to learning contexts and ultimately grounded in “the power of an institution and conformity to convention” (Kress, 2013). In other ways, Kress’s call for “a re-calibration of pedagogic relations congruent with contemporary social givens” not only resonates with contemporary LS work, but also holds promise for the continuing development of the field. Kress emphasizes that learning researchers’ practices of recognition must remain attuned to the semiotic work of learners and teachers, to how they “realize meaning” through producing and using signs, in multiple modalities, within and across contexts. In so doing, learning researchers, he argues, are better able to attend to the agency involved in learning contexts, and thus to meet the challenge posed by Stevens (2010), who calls for LS to be an endogenous science, that is, to look “from within” at the work being done in and across learning contexts.

The papers in this session are tied together through an interest in the design and study of meaning making in and across multimodal contexts. We draw on existing work in the learning sciences and also explore new ways of understanding signs of learning. We engage with creative, agentic aspects of learning, and attend to sociomaterial practices that function as “pedagogical pivot points in enabling critical learning and social change” for learners often forgotten about in the current market driven education system (McKenzie & Bieler, 2016, p. 16). We attend to the multimodal and multisensory and how they mediate the production of learners and learning, and to “the agency evident in semiotic work” that offers new possibilities (Kress, 2013, p. 129).

The papers explore different research sites and imaginaries, marked in different ways by globalization, mobility, diversity, and inequity. Gutiérrez's (2014) metaphor of "learning as movement" helps us ask new questions about "what takes hold as people, tools and practices travel across activity settings of everyday life, and on how individuals develop, repurpose and reorganize repertoires" (p. 48). We document learning of "border crossers," who must learn "to negotiate the power, violence, cruelty of the dominant culture" through their "own lived histories, restricted languages, and narrow cultural experiences" (Giroux, 2012, p. 13). Hence, we not only unsettle learning but its grounding in Western and Indigenous epistemologies and methodologies. We address issues of design, expanding on issues that Bang and Vossoughi (2016) judge to be essential to "create sustainable and transformative change." Building on the work of sociocultural and semiotic theory and challenging current neoliberal ideals about what counts as knowing, learning, becoming and who can come to know, we aim to engage in a dialogue with the audience about new ways to recognize and engage with learning.

Identity, agency and subjectivities of Afro-diasporic teachers in STEM classrooms

Jennifer Adams

Introduction

This presentation describes "signs of learning" in relation to the emerging professional identities of new teachers of colour. It is a part of a larger study that articulates relationships between science teacher identity and learning to teach with an emphasis on informal science teacher education. Responding to calls for greater collaboration between science-rich informal institutions and teacher education programs, this research focuses on exploring aspects of teacher identity that related to their learning to teach experiences with informal science institutions.

The study is situated in a large, diverse urban public school district that has long-standing issues with science teacher recruitment and retention and student performance in STEM, especially that of racialized, minoritized and economically marginalized students. In this paper I examine the lived experiences of three female new teachers (within their first three years of teaching) of colour in science classrooms as they navigate their identities and subjectivities of teaching and learning to teach vis-à-vis the racialized storylines around schooling in general and STEM education specifically. I unpack the discursive fields in which they exist, particularly the narratives around disparities of Black and Latinx people in STEM how their own racialized subjectivities shifted and responded to these discourses, and the ways that they adapted meanings of informal science learning in these enactments.

Theoretical and methodological approach

Nasir et al. (2012) frame relationships among race, racism and learning through racial storylines—pervasive narratives about race in social discourse that get enacted in schools and other settings. Racial storylines make identities available to learners (and teachers) in learning contexts, in turn influencing how people are positioned and position themselves. With learning, goals, and identity being "three prongs of a triangle, with bidirectional arrows between each two points" (p. 294), evolving together in social practice, racial storylines offer spaces where learners could resist, articulate new goals and take up new identities.

In learning settings, teachers are both subjected to the racial storylines as individuals while also shaping learning experiences for their students, often in response to these narratives. Agency describes how one accesses and appropriates resources in a given field in order to meet goals (Adams & Gupta, 2017). Teacher agency is the belief that the teacher-self is capable of making the right instructional decisions, knows how to acquire and use resources to teach, and confident about creating and maintaining a safe and effective learning environment for all learners to meet instructional goals. For science teachers, agency also means confidence in content knowledge and ability to motivate and sustain science learning in all students. Racial storylines present a challenge in that it often positions people of colour counter to positive science achievement. Therefore how a teacher learns to respond to the racial storylines in practice, with equitable science learning central to being an effective science teacher, contributes to agency and subsequently identity.

This study draws from two and a half years of data from a group of science teachers who met bi-monthly as a collaborative teacher inquiry group. The teachers are middle and high school science teachers in a large, public, urban system. The meetings were structured around co-generative dialogues—structured dialogues around shared events or practices—that aim to generate new understandings, meanings and practices (Martin, 2006). During these meetings teachers shared experiences and artifacts (lesson plans, pictures, videotapes, etc.) for group analysis and discussion. Three participants emerged for analysis in this paper because of their identities as Afro-diasporic teachers coupled with their enactments of teaching. Individual interviews and one-

on-one informal dialogues also informed this study. I am also a Black woman who taught high school science in the same public system. Engaging in reciprocal vulnerability (Kohli, 2014) I shared my experiences of learning to teach, teaching, and educating teachers as well as my experiences with race vis-à-vis these contexts.

Identities and subjectivities are made and remade through discourses, i.e., recurrent themes or storylines: “discourses...mark out identifiable systems of meaning and field of knowledge and belief that, in turn, are tied to ways of knowing, believing, and categorizing the world and modes of action” (Luke, 1995). During the analysis, I specifically looked for a) what storylines emerged, b) how they viewed themselves vis-à-vis these storylines and c) they ways that these storylines influence their becomings/identities as teachers.

Findings

Within the different contexts, teachers enacted teaching in different ways in relation to how they viewed themselves vis-à-vis their students. Their goals for creating STEM learning experiences were shaped and enacted around STEM futures that they imagined for their students and to counter the prevailing deficit discourses around students of colour and STEM. Teachers challenged and resisted storylines by developing structures that allowed their students to create alternative narratives and imagine a broader range of futures for themselves: weekend science-related field trips, interactions with graduate students and scientists of color, creating new activities and out-of-classroom learning spaces, etc.

The three teachers defined and redefined informal science teaching in ways that resonated with their identities as teachers and how they viewed themselves in relation to their students. In describing their identities as teachers, it is hard to separate their professional and social identities as they are both present and continuously influenced the other, thus “I am a black teacher, and because I am a black teacher I function in *this* way in *this* classroom.” *This* classroom speaks to the complexities of urban schools and classroom in that although all three teachers teach within the same public school system, each of their schools and classrooms diverge in the students and resources that structure them.

In dreaming of and creating possibilities for their students, these teachers engage in the emotional/psychological labor of the constant struggle to resist the racial storylines of people of color in relation to science and school, for themselves and their students.

Retracing the experiential trajectory of Science and Technology teachers’ as they change the pattern of their teaching practice and engage in curriculum development.

Sylvie Barma, Marie-Caroline Vincent, and Samantha Voyer

Introduction

The curricula of several Western nations have made a priority of improving the contextualization of Science and Technology (ST) education through the study of problems with relevance to the lives of students (Barma, 2011). Roth & Lee (2004) argue that teachers should avoid creating learning environments that funnel students into performance-based tracks and should instead offer students a broad variety of situations conducive to participation enabling them to make decisions in line with their own interests. ST education should be understood in terms of the definition provided by Fourez (2002, p. 198, our translation), for whom it is a “person’s capacity, in a sociotechnical society, to build for him or herself a field of autonomy, communication and negotiation with his or her environment”. Teachers are thus considered sense makers instead of grade makers. It challenges encapsulated forms of school activity (Engeström and Sannino, 2010). Our contribution documents the trajectory of the professional development of three science teachers engaged in designing a new form of practice for learning and expanding.

Context

In 2006, Quebec ST teachers were asked to integrate technological design of prototypes to support the appropriation of scientific concepts (MELS, 2006). However, after the implementation of the curriculum, there was a great lack of teacher training and tensions rose. From 2010 to 2017, we engaged in a school-university partnership with three ST teachers coming from different schools. They acted as collaborators and co-creators to co-model prototypes for workshop activities. Over the seven years, more than 165 teachers, lab technicians and pedagogical counselors coming from 15 school districts benefited from five workshops co-produced by the participants for their peers’ professional development. We documented the agency and actions of the three leading teachers as they engaged in the co-design of new curricular materials in the form of concrete artefacts to be presented to their colleagues as an opportunity to modify their practice. The results presented will describe

why, how and where ‘meaning-making’ took place and how, over the years, the individual and collective creativity changed the development of their professional practice. The participant teachers actively worked to shape their new form of practice and got involved.

Theoretical framework

We use the key concept of boundary to understand the activity under construction (teachers’ professional development). Boundaries are “established distinctions and differences between and within activity systems that are created and agreed on by groups and individual actors during a long period of time while they are involved in those activities” (Kerosuo, 2006, p. 4). The metaphor of “learning as movement” helps us ask new questions about “what takes hold as people, tools and practices travel across activity settings of everyday life, and on how individuals develop, repurpose and reorganize repertoires” (Gutiérrez, 2014, p. 48). According to Vooght et al. (2015), partnerships constitute a move from within, instrumental in exploring new ways of teaching and learning. Those ways take a variety of forms and shapes and involve boundary crossing as tensions arise and are overcome (Engeström, 2001). To document “what is not yet there” we adopted the theory of Expansive Learning, focusing on individual and joint agency to understand why and how participants collectively created new artefacts that revealed key boundary crossing instruments. We document how teachers created “sustainable and transformative change” that had an impact on their educational communities (Bang & Vossoughi, 2016).

Methods

We adopted a collaborative and interventionist methodology to document the co-design of the teachers’ professional development (Barma et al., 2017). Ethnographic data was collected over the seven years in the form of audio-video recordings of teacher training sessions, interviews and photographs during co-teaching sessions, and artefacts produced by the team (teaching documents, YouTube videos, prototypes, online resources, administrative documents, speaking turns, etc.). We pooled in (‘bricolage’) all the data gathered over the seven years and analyzed them in keeping with the experiential trajectories of the participants (Kincheloe & Berry, 2004). Focusing on individual and joint agency allowed us to understand why and how participants engaged in expansive learning and came to collectively progress to create new tools that revealed boundary crossing objects and determined new roles to reconceptualised the object of their joint activity. The construct of a hybrid space in the form of a new activity implies that multiple levels of activity systems expand their own activity to establish a zone of proximal development and boundary crossers were identified as key players between activity systems.

Findings

Findings will be presented as a narrative, respecting the chronological development of the participants’ agency and creativity as well as the unfolding of the co-design of artefacts. As the participants reflected on their productions and experiences, their professional identities evolved and redefined the borders of their teaching activities. The data is still under analysis but, already, we are able to reconstruct an experiential trajectory of the reconfiguration of the teachers’ practice in response to their need for professional development. For example, different co-designed prototypes were presented during 6 teacher training sessions where 165 peer-teachers, student-teachers, lab technicians and pedagogical counselors of 15 different school districts participated. These prototypes were created to integrate several elements of the ST curriculum and implemented with high school students. We presented the prototypes to 124 university student-teachers during didactic classes and crossed another unexpected border. Quantitative data was also collected through seven online questionnaires. We obtained a total of 776 students’ responses and a total of 39 responses from teachers with relation to their own relationship to ST education. Three sections will orient the presentation of the narrative: 1) critical contexts, questioning and resistance to change; 2) contexts of discovery, creativity and modelling of new forms of practice and 3) contexts of practice and the social relevance of the integration of the tools produced in the community. The issues of teachers’ will to design for learning and expanding was traced back in their individual and collective agency as well as in the artefacts that acted as boundary crossing objects.

Coding science as boundary Work: The role of publicness in scientific computing

Pratim Sengupta, Marie-Claire Shanahan, Stephanie Hladik, and Dylan Paré

Objective and theoretical background

For Papert (1987), technocentrism was the fallacy of referring all questions about technology to the technology itself. Despite Papert’s call to action, educational computing has predominantly reified and perpetuated

technocentric images in which learning to code has become synonymous with the “proper” use and production of computational abstractions (Sengupta et al., 2018). In contrast, we argue that rather than viewing computing as regurgitation and production of a set of axiomatic computational abstractions, scientific computing using open source code in public spaces that invite playful engagement can be reconceptualized as boundary work.

We conceptualize science and computing as figured worlds (Sengupta & Shanahan, 2017). Holland et al. (1998) argue that individuals’ identities and agency both constitute and are constructed within cultural realms, or figured worlds, in which particular characters are recognized, significance is assigned to certain acts, and particular outcomes are valued over others. Gieryn (1999) defined “boundary work” as the continuous acts of figured world creation that scientists engage in when they frame their work through what it is not (“not-religion,” “not-mechanics,” “not this kind of research but that kind”).

Sengupta & Shanahan (2017) introduced public computing as a new form of open-ended, public learning environments, in which visitors can directly access, modify and create complex and authentic scientific work through interacting with open source computing platforms. Framed phenomenologically, technology should be viewed not only as ways and means of performing disciplinary work, but also in light of broader norms of participation in disciplinary and ancillary cultures developed around localized technological infrastructure. We posit that when placed in the public domain—both as a public space and in the form of open source code—where members of the public can freely access, alter and manipulate the code—scientific computing becomes freed from being beholden to narrowly forms of disciplinary authenticity. Scientific code, in such contexts, becomes a boundary object, their ill-structured nature allowing them to have different meanings in the different social worlds that they cross and therefore to be acted on in completely different ways.

Method

This paper presents ethnographic analyses of the experiences of teaching and learning coding across two different contexts of public computing: a science and technology museum (M), and a public space within a University (U). The participants include children 10 years and above and their parents (in settings M and U), museum facilitators who act as teachers (in setting M), students and pre-service teachers (who act as both teachers and learners in setting U). In each setting, we designed an open source, interactive exhibit allowing visitors to directly interact with open source simulations of complex systems. These simulations modeled how flocks emerge from simple rules of interactions between many individual-level virtual agents, allowing any visitor to modify the underlying open source code. We conducted participant observations over a period of 15 months in each setting.

Analysis and findings

We show that the experience of coding in these settings can be conceptualized as *boundary work* (Gieryn, 1999), i.e., continuous acts of creating “as if” worlds that learners jointly engage in along with their parents, teachers and facilitators, where they frame their work as “coding” through comparing with other disciplinary frames. These lateral frames are initiated by the interest of learners (and in some cases, parents and facilitators) in disciplines other than computing, and by their personal narratives and interpretations. Our analysis also illustrates how code fragments serve as *pivots*, artifacts that shift the frame of an activity and evoke or “open up figured worlds” (Holland et al., 1998, p. 61). Working directly with the code pivoted visitors partially and playfully into the designers’ figured worlds. We identify how specific fragments of the code may have served as pivots, allowing play between larger disciplinary cultures in which the designer’s and visitors’ figured worlds of the simulation were embedded. A final key finding is that *teaching* coding, in these informal spaces, often requires facilitators to step back and let these other disciplinary frames come in. The work of the teacher as designer can therefore be understood as facilitating back and forth movements between these frames, an image of reflection in action that further urges us to move beyond technocentric images of coding and teaching coding.

Significance

Our work challenges epistemologies of certainty (Dewey, 1929), in the context of democratizing disciplinary cultures of science and technology and suggests that an emphasis on publicness within the technological infrastructure, especially in the context of educational and scientific computing, can potentially create spaces for playful representational and epistemic uncertainties, which in turn can make it possible for science and technology to become *public* experiences.

Youths’ circulations in STEM networks of multiple scales: Case studies of agency and transformation of self and practice

Objectives

Studies of youth circulations within complex networks of STEM practices over time have led to the documentation of moments of youth agency and the temporary overcoming of injustice (Bang & Vossoughi, 2016; Bricker & Bell, 2014). Yet, we still need to better understand: 1) how youth engage locally in creative, agentive meaning making in science, 2) how youth address injustice as they enact agency through local and global meaning making, and 3) how adults may open up spaces for the development of critical agency and meaning making that challenge deeply rooted historicized oppression.

Theoretical framework

We invoke a conceptual reading of STEM practices as a complex matrix of practices (Leander et al., 2010). Imperative is a focus on relations among practices and the tracing of youths' circulations, agency, and transformations within and across practices, next to implications for social justice in STEM. We juxtapose analysis of local meaning making and explore "signs of learning" as emergent from youths' multimodal, multivoiced, embodied, and creative enactment of science. We rely on video analysis, attending to embodied action rather than just discourse or "the moving image" (de Freitas, 2016). We focus on the affective and emotional that transpires and constitutes the kind of complex dances of meaning making that we document.

Data sources

We present two case studies. Case 1 examines elementary children's engagement with science in a space between school and out-of-school, a community organization offering access to meaningful activities in science, mathematics and robotics to enrich the education of children in schools in underserved communities. Case 2 draws from a multi-sited ethnography tracing a cohort of six girls for seven years beyond their participation in an afterschool program. The narratives of each case emerged from a bricolage (Kincheloe & Berry, 2004) of multiple data sources (participant observation, video-ethnography, interviews, youth initiated joint productions).

Results

Case 1 tells the story of two teams engaged in two different science activities, one implying extraction of DNA from a strawberry, following a session on DNA and the creation of a DNA chain, while the second activity implied dissection of a plant. We noted an interesting tension between children's engagement in "administrative science" and successful pursuit of the science protocol, and moments of "realizing meaning" made possible through the manipulation of the tools in creative ways owned by the children, supported by exchanges with each other and by positioning one another as doers of science. The case makes evident the value of analysing situated and practical experiences in which materials and selves are entangled in ways that make them pivots for learning and becoming in science. Case 2 explores circulations and learning on the move of Achyntia and Alana. We make evident the power of sisterhood and affinity that supported the girls' circulation among diverse STEM practices beyond the afterschool program, into high school, and later, higher education. The case makes evident how the two girls became agents of circulation by opening up spaces of the STEM network for each other, as their paths crossed, and as they shared ongoing struggles as youth of color and insiders of STEM.

Significance

The cases offer rich insights into circulations of bodies, epistemologies of science, and identities in science. They challenge what it means to make meaning in science and the long-held vision of a linear STEM pathway. Both explore youth circulations, yet at different scales: one within a science project, the other across practices over time. Both point to social justice in STEM as emergent, as affectively charged, and as implying a sense of belonging, sustained by youths' circulations, grounded locally and globally in supportive communities. The two cases raise methodological issues of scale, in particular the challenge of having others recognize these moments as signs of learning. Youths' agency and transformations of learning environments in ways they valued remained marginalized and essentially unattended to by others in power. To conclude, we discuss the complex dynamic of oppression at work and its implications for social design based research but also methodology.

Learning that matters: Critical science agency in and through teen women's film production

Rachel Chaffee, April Luehmann, Day Greenberg, Jessica Thompson, Sara Haganah, and Angela Calabrese Barton

Introduction

New ways of recognizing learning can aid in reconfiguring STEM learning opportunities and lenses whose current inertia cements an unwelcome environment for youth already marginalized in STEM. Working with teens engaged in out-of-school learning allowed us to investigate how three groups of teen women took up and *re/shaped* science for their own purposes through STEM film projects. We explored what aspects of film-making served as transformational pedagogical pivots for inviting teens' Critical Science Agency (CSA), i.e., the ability to collectively leverage scientific understanding in conjunction with other forms of expertise to identify, investigate and take actions on problems that matter within the community and that relate to justice-oriented issues. Here, we explore CSA as one expansive outcome promoting more equitable engagement and futures in science and engineering (S/E). CSA offers important *pivots* into deeper engagement with science knowledge and practice as well as into the contexts in which their science-related concerns take place. Pivots are "mediating or symbolic devices" not just to "organize responses, but also to pivot or shift into the frame of a different world" (Holland et al., 1998, p. 50). When youth leverage their funds of knowledge, they etch their insideness onto their work in ways that impact the design process, how/where it unfolds, and their roles in it. As pivots, these funds are not simply complementary to the youths' investigations, but *essential* to *who they are and their project work*. We asked: 1) How and why did teen scientists develop and use repertoires of practices across their films?; and 2) How was power re/negotiated through youths' acts of CSA, and what served as transformational pivot points for developing that agency?

Cross-site methods

We engaged in multimodal analysis of four films created by four sets of young women in three different out-of-school contexts serving low-income populations of color. Beginning with the construction of five transcripts for each film that documented interpretations of youth's productions by foregrounding five unique lenses (auditory, visual, editorial, cinematographic, and background), we coded choices youth made in recruiting and organizing resources in particular arrangements within filmic episodes, across trajectories of episodes, and in overall film productions (Halverson, 2013). We repeated this process for all films before cross-analyzing the film data. This process of visual analysis allowed us to identify young women's efforts to enact CSA through multimodal representations of themselves and the science in which they engaged.

Findings

Analysis across the four films revealed patterns of prioritizing issues of caring: for the local environment, for family and community members, for peers suffering with depression, for animals. Teen-developed repertoires of practice, emerging within and across films, consisted of repeated forms of framing, sources of motivations, and processes of meaning-making. First, each group of teen filmmakers constructed global narratives to sequence the film by introducing themselves as investigators, detailing a problem of significance to them, describing their varied S/E inquiry endeavors, and sharing their research findings with their audience(s). Second, teen women consistently acted and spoke as a collective "we" across episodes, centering *their* collective voices in the investigation, outcomes, and implications of the work. All four films evidenced teens' overlapping attention to expectations of varied cultural memberships as they embodied S/E learning: addressing accountabilities of science while also attending to cultural expectations of being a teenager (music choices, cartoons), being a teen woman (removal of Hijab in all girl space), and a filmmaker (credits, transitions, candid and full-frontal shots). In doing so, S/E productions foregrounded the humanity of doing S/E work, thus recentering themselves in S/E.

Film production *supported* and *reflected* moments of developing and enacting CSA through dynamic and purposeful use of *transformational pivot points*. Teen filmmakers re/negotiated traditional STEM power structures by positioning themselves as authors and owners of STEM investigations and designers of socioscientifically informed solutions, leveraging funds of knowledge, and collectively making S/E contributions with implications for intended audience action. They capitalized on multimodal affordances of film production: text overlays for counternarration, coupling of moving and still images for representing multidimensional identity and skill development in-the-moment, full frontal shots with eye contact for claiming physical presence in STEM, dramatic role play as radical reenvisioning of scientific communication). Teens pivoted science and digital technology to merge personal stories with scientific understandings, to invite external expert perspectives while maintaining story ownership, and to simultaneously address diverse cultural expectations. Films documented the investigative process and taught the science behind the investigations through traditional artifacts like charts and graphs as well as through non-traditional methods of science practice and teaching. Filmmakers drew from community memberships while simultaneously leveraging the project to develop new social networks/coalitions to advance their work towards their goals of change.

Significance

The study demonstrates the power of youth-driven multimodal production to afford rich opportunities for CSA. Through the publication of their films, teen women challenged current conceptions of who can do meaningful science and engineering, in what ways, and toward what ends. The need for this work is underscored in the need to recognize diverse forms of participation and production for students who have been traditionally marginalized. Foregrounding the role of CSA in S/E shifts the process and outcomes of learning from a primary focus of developing and deepening practice-based S/E understandings to one of enabling and empowering individuals and communities to leverage S/E knowledge in ways that matter to them in the present.

References

- Adams, J. D., & Gupta, P. (2017). Informal science institutions and learning to teach: An examination of identity, agency, and affordances. *Journal of Research in Science Teaching*, 54(1), 121-138.
- Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction*, 34(3), 173-193.
- Barma, S. (2011). A sociocultural reading of reform in science teaching in a secondary biology class. *Cultural Studies of Science Education*. doi:10.1007/s11422-011-9315-9
- Barma, S., Laferrière, T., Lemieux, B., Massé-Morneau, J., & Vincent, M.-C. (2017). Early stages in building hybrid activity between school and work: the case of PénArt. *Journal of Education and Work*, 30(6), 669-687. doi:10.1080/13639080.2017.1294247
- Bricker, L. A., & Bell, P. (2014). "What comes to mind when you think of science? The perfumery!": Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, 51(3), 260-285.
- de Freitas, E. (2016). The moving image in education research: Reassembling the body in classroom video data. *International Journal of Qualitative Studies in Education*, 29(4), 553-572.
- Engeström, Y. (2001). Expansive learning at work : toward an activity theoretical reconceptualization. *Journal of Education*, 14(1).
- Gieryn, T. F. (1999). *Cultural boundaries of science: Credibility on the line*. University of Chicago Press.
- Halverson, E. (2013). Digital art making as a representational process. *Journal of the Learning Sciences*, 22, 121-162.
- Holland, D., Lachicotte, W. Jr., Skinner, D., Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard.
- Kincheloe, J. L., & Berry, K. S. (2004). *Rigour and complexity in educational research: Conceptualizing the bricolage*. McGraw Hill, England: Open University Press.
- Kerosuo, H. (2006). Boundaries in action. *An activity-theoretical study of development, learning and change in health care for patients with multiple and chronic illnesses*.
- Knappett, C. and Malfouris, L. (2008) *Material agency*. New York: Springer.
- Kress, G. (2013). Recognizing learning. In I. de Saint-Georges and J.-J. Weber (Eds.), *Multilingualism and multimodality* (pp. 119-140). Sense Publishers: Rotterdam.
- Leander, K. M., Phillips, N. C., Taylor, K. H. (2010). The changing social spaces of learning: Mapping new modalities. *Review of Research in Education*, 34, 329-394.
- Luke, A. (1995). Chapter 1: Text and discourse in education: An introduction to critical discourse analysis. *Review of research in education*, 21(1), 3-48.
- Nasir, S. N., Snyder, C. R., Shah, N., & Ross, K. M. (2012). Racial storylines and implications for learning. *Human Development*, 55(5-6), 285-301.
- Papert, S. (1987). Information technology and education: Computer criticism vs. technocentric thinking. *Educational Researcher*, 16(1), 22-30.
- Sengupta, P., & Shanahan, M. C. (2017). *Boundary Play and Pivots in Public Computation: New Directions in STEM Education*. *International Journal of Engineering Education*, 33(3), 1124-1134.
- Sengupta, P., Dickes, A., & Farris, A.V. (2018). Toward a phenomenology of computational thinking in K-12 STEM. In Khine, M.S., (Ed). *Computational Thinking in STEM: Foundations and Research Highlights*. Springer.
- Stevens, R. (2010). Learning as a members' phenomenon: Toward an ethnographically adequate science of learning. *Yearbook of the National Society for the Study of Education*, 109(1), 82-97
- Wilson, S. (2008). *Research is ceremony: Indigenous research methods*. Halifax, NS: Fernwood.
- Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science*, 43(2), 259-282.