Beyond Technocentrism

Supporting Constructionism in the Classroom

Karen Brennan • Harvard University, USA • karen_brennan/at/gse.harvard.edu

> Context • In 2015, we are surrounded by tools and technologies for creating and making, thinking and learning. But classroom "learning" is often focused on learning about the tool/technology itself, rather than learning with or through the technology. **> Problem** • A constructionist theory of learning offers useful ways for thinking about how technology can be included in the service of learning in K-12 classrooms. To support constructionism in the classroom, we need to focus on supporting teachers, who necessarily serve as the agents of classroom-level innovations. This article explores a central question: How can we support teachers to engage with constructionism as a way to think beyond a technocentric view in the classroom? **> Method** • I approach this work from the perspective of a designer, using the process of supporting teachers working with the Scratch programming language in K-12 classrooms as a central example. I draw on reflections from six years of the ScratchEd project, which includes interviews with 30 teachers, and observations from teacher professional development events and an online community of educators. **> Results** • I describe five sets of tensions that I encountered while designing the ScratchEd model of professional development: tensions between (1) tool and learning, (2) direction and discovery, (3) individual and group, (4) expert and novice, and (5) actual and aspirational. I describe how these tensions are negotiated within the elements of the PD model (an online community, participatory meetups, and an online workshop). **> Implications** • The tensions I describe are not specific to Scratch, and can serve as a more general model for PD designers to scrutinize and critique. **> Constructivist content** • This work contributes to ongoing conversations and questions about how to support constructivist/constructionist approaches in classrooms. **> Key words** • **Constructionism, technocentrism, teachers, professional development, ScratchEd.**

Technocentrism

« 1 » In the mid-1980s, Seymour Papert wrote a position paper entitled *Computer Criticism vs. Technocentric Thinking*. A principal argument of the paper was that conversations about technology and learning too often begin and end with the technology itself, without acknowledging the complexity of the environment in which the technology is situated. Papert described this technology-limited view as *technocentrism*.

> "Technocentrism refers to the tendency to give […] centrality to a technical object – for example computers or Logo. This tendency shows up in questions like 'What is THE effect of THE computer on cognitive development?' or 'Does Logo work?' Of course such questions might be used innocently as shorthand for more complex assertions, so the diagnosis of technocentrism must be confirmed by careful examination of the arguments in which they are embedded. However, such turns of phrase often betray a tendency to think of 'computers' and of 'Logo' as agents that act directly on thinking and learning; they betray a tendency to reduce what are really the most important components of educational situations – people and cultures – to a secondary, facilitating role." (Papert 1987: 23)

« 2 » Thirty years later, very little has changed. In 2015, we are surrounded by tools and technologies for creating and making, thinking and learning. But when learners encounter this wide range of technologies in the classroom, their experiences are still too often centered on technology itself (Buckingham 2007; Cuban 2001; Kimmons 2015; Selwyn 2011; Selwyn 2014). The "learning" is focused on learning *about* the tool/technology or the effects of the tool/technology itself, rather than learning *with* or *through* the technology. The questions that are asked about impacts and outcomes strive to isolate the technology as the source of change. We still seem hopelessly stuck in a technocentric view.

« 3 » How, then, can we defend against technocentrism in the K-12 classroom? Taking an extreme approach, we could exclude digital and network technologies from core classroom experiences, reducing their role to that of peripheral luxuries, to be indulged only occasionally. Although this approach may appeal to some, it is fundamentally untenable. Technology is an important part of our world and young learners are better served by gaining fluency with technology than by avoiding it. And beyond arguments about the centrality and significance of technology in modern life, technology can also play an important role in supporting learning processes (Collins & Halverson 2009; de Jong & Pieters 2006: 740). Digital and network technologies can serve as powerful mediums for communicating understanding, connecting learners, and constructing knowledge.

« 4 » Rather than uncritically embracing or rejecting technology, we should consider how best to include technology in the service of classroom learning. Part of this work is technocentric – basic understanding of technology is a necessary precondition

http://www.univie.ac.at/constructivism/journal/10/3/289.brennan

for learning with and through technology. But while a focus on technology itself may be a starting point, this approach will not, by itself, result in a more transformative trajectory of use (Liff & Shepard 2004). To achieve this, technology needs to be accompanied by a clear theory of learning, guiding the use of technology in the service of learning (Lajoie & Azevedo 2006: 803).

« 5 » In this article, I argue that a *constructionist* theory of learning offers useful ways for thinking about how technology can be included in the service of learning in K-12 classrooms. Constructionism focuses on the significance of culture in learning, while simultaneously offering a meaningful role for technology in learning – objects, tools, and technologies offer new modes and means for learning through constructing, designing, and making. To support constructionism in the classroom, I further argue that we need to focus on *supporting teachers*, who necessarily serve as the agents of classroom-level innovations (Borko 2004: 3).

« 6 » Responding to the call from Hugh Gash (2014: 306) that "the striking educational question to ask now is how to think about the teachers' role in the 21st century," I explore a central question: *How can we support teachers to engage with constructionism as a way to think beyond a technocentric view in the classroom?* I approach this work from the perspective of a designer, using the process of supporting teachers working with the Scratch programming language in K-12 classrooms as a central example, highlighting the complexities and tensions involved in helping teachers through professional development opportunities. For the past seven years, my research has focused on studying and supporting constructionist approaches to learning with the Scratch programming language, particularly in formal learning environments such as K-12 classrooms. The ideas in this article draw on reflections from six years of the ScratchEd project, which includes interviews with 30 teachers, and observations from teacher professional development events and an online community of educators.

« 7 » The remainder of the article is organized into four sections. In the first section, "Defining constructionism," I provide a definition of constructionism as a set of classroom practices. In the second section, "Supporting teachers," I outline the elements of a model that I have been developing to support teacher learning, including an online community, participatory meetups, and an introductory workshop. In the third section, "Negotiating tensions," I discuss the tensions that I have experienced in developing the model and offer examples of how I have negotiated those tensions in each of the three elements of the model. In the conclusion, "Beyond technocentrism," I end with comments on the relationship between technologies and theories of learning.

Defining constructionism

« 8 » Although *constructivism* is a term familiar to most teachers, *constructionism* is not. I frequently share a favorite excerpt from Yasmin Kafai and Mitchell Resnick as definition.

> "[Constructionism] builds on the 'constructivist' theories of Jean Piaget, asserting that knowledge is not simply transmitted from teacher to student, but actively constructed by the mind of the learner. Children don't get ideas; they make ideas. Moreover, constructionism suggests that learners are particularly likely to make new ideas when they are actively engaged in making some type of external artifact, […] which they can reflect upon and share with others." (Kafai & Resnick 1996: 1)

« 9 » Constructionism is grounded in the belief that the most effective learning experiences grow out of the active construction of all types of things, particularly things that are personally or socially meaningful (Bruckman 2006; Papert 1980), that are developed through interactions with others as audience, collaborators, and coaches (Papert 1980; Rogoff 1994), and that support thinking about one's own thinking (Kolodner et al. 2003; Papert 1980). I argue that these four aspects – learning through the activities of *designing*, *personalizing*, *sharing*, and *reflecting* – are essential to the design of constructionist learning environments. Each of these activities has an extensive literature associated with it; in the following sub-sections, I draw attention to a few of the key ideas, themes, theories, and concepts that have been most helpful to my understandings.

Designing

« 10 » There are competing narratives about the relationships between young people and digital technology. One popular narrative is that of the "digital native" – kids who were "born digital" and belong to the "digital generation" (Palfrey & Gasser 2008; Prensky 2001; Tapscott 2008). This narrative is often centered on an assumed familiarity and fluency with computation, the idea that young people have innate understandings that elude adults – parents and teachers, cast as "digital immigrants."

« 11 » Descriptions of digital natives' activities and participation that draw on exemplars or ideal types, such as Henry Jenkins et al.'s (2006) "core media literacy skills" and Mizuko Ito et al.'s (2009) "hanging out, messing around, and geeking out" participation modes, have elicited criticism for misrepresenting the "often unspectacular" interactions between young people and technology (Selwyn 2009: 364).

« 12 » Digital native narratives tend toward an exaggerated or undifferentiated view of technology use, in which all forms of interaction with digital technologies are valuable and all types of participation offer equally interesting opportunities for learning. David Buckingham provided a broad critique of the young-person-as-technology-elite narrative, arguing that the narrative is less of an observation than an aspiration for creative uses of technology – that positioning young learners as digital natives is "not a description of what children or young people actually are, but a set of imperatives about what they should be or what they need to become" (Buckingham 2007: 15).

« 13 » In particular, creative activities such as designing and making with digital technologies are relatively uncommon in the practices of young people. This is partly due to the nature of the technologies themselves – for example, the preponderance of "edutainment" software, and the paucity of construction-oriented software (Ito 2009). But it is also partly due to the lack of visibility and value in school culture (and beyond) of design thinking, with young people reluctant to see the complexities of design activities "as opportunities rather than as things to be avoided" (Fischer 2002: 25).

« 14 » Constructionist approaches to learning, which value learning through de-

sign activities, respond by engaging young people in iterative thinking, problem-solving practices, and critical creativity, which serve as foundations for learning (Harel & Papert 1990; Kafai 1995; Kolodner et al. 2003; Krajcik & Blumenfeld 2006). Designing necessitates the ability to identify and negotiate constraints, clarify and manage ambiguity, and, fundamentally, persist and engage in hard work (Fischer & Nakakoji 1997; Razzouk & Shute 2012; Sawyer 2006; Seiter 2008).

Personalizing

« 15 » In contrast with the structures common in modern education, such as large class sizes and homogeneous curriculum, constructionism recognizes the importance of the individual. Personalizing, as a constructionist aim, means that the design of learning experiences should consider how to engage an individual learner on multiple levels, including cognitive and affective.

« 16 » The cognitive perspective on personalization traces back to constructionism's main influence – Piaget and constructivist assumptions about learning. In constructivist theories of learning, learning is not something done *to* learners, but rather something done *by* learners. Learners are not filled with knowledge and new ideas by the world around them; they engage in processes of adaptation. Engaging with new ideas leads to *assimilation*, by taking new ideas and connecting them to already-established understandings – or to *accommodation*, by modifying already-established understandings in consideration of new ideas (Ackermann 1996; Koschmann et al. 1996; Piaget 2007; Riegler 2005). Understanding and supporting learning necessarily means creating opportunities to make sense of the individual, personal connections that learners form to what they are learning.

« 17 » Part of this sense-making involves thinking about differences in individuals' learning styles and self-concepts, and recognizing that there is not one way or style of learning. There are numerous examples of frameworks that seek to extend the ways in which learners see themselves and are seen by others. Howard Gardner's multiple intelligences (1983, 1991, 1999) aimed to dislodge some of the privilege associated with linguistic and logical/mathematical capacities, by drawing attention to other capacities, such as musical, spatial, and inter/intrapersonal. Carol Gilligan's (1982) reinterpretation of Lawrence Kohlberg's stages of moral development sought to displace masculinist assumptions about self versus other. Carol Dweck's (2000) entity and incremental theories of intelligence provided ways of thinking about how to support students productively, by challenging assumptions about ability, success, praise, and confidence. Sherry Turkle and Seymour Papert (1990), in critiquing Jean Piaget and Bärbel Inhelder's privileging of formal reasoning, argued for recognition of both bricoleur and planner approaches, particularly in the planner-dominated culture of computation. These frameworks deserve the attention of learning environment designers, and should encourage thinking about how individual learners are more or less productively engaged by different strategies.

Sharing

« 18 » Learning and development have important individual components (as articulated in "Personalizing," from the perspective of Piaget's work). But they are also deeply social processes. Lev Vygotsky extended the Piagetian framing of the individual's cognitive processes by introducing the notion of the *zone of proximal development* (ZPD), defined as

> "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (Vygotsky 1978: 86)

Vygotsky's notion of the ZPD expanded the boundaries of individual cognition, including other people and their abilities as part of an individual's capacities for taking on challenges of increasing difficulty (Cole & Wertsch 1996).

« 19 » Theories about communities of practice and situated learning further extend thinking about how others support learning, in particular, how community settings can provide access to other learners and artifacts (Brown, Collins & Duguid 1989; Lave & Wenger 1991; Rogoff 1994). In this literature, apprenticeship is a recurring metaphor for the type of learning that can take place, introducing new ways of thinking about the learner and the people around the learner who are helping them (Collins 2006; Lave & Wenger 1991; Wenger, McDermott & Snyder 2002). Learners are gradually folded into relationships with other learners, understandings of the enterprise of the learning, and familiarity with the objects and practices of the community – learning from those with greater experience and expertise, in a process that Jean Lave and Etienne Wenger (1991) described as *legitimate peripheral participation*.

« 20 » More recent research has described the ways in which the social nature of learning serves as essential motivation and support for young people's participation in digital culture, particularly in the context of online interactions (Buckingham & Willett 2006; Ito et al. 2009; Jenkins et al. 2006). Whether hanging out with friends or playing games or remixing media, having access to others makes for better participation, as young people are able to support each other in understanding practices and norms. Amy Bruckman's (1998, 2006) work described the cognitive, social, and psychological benefits that an online community provided for individual learners in constructionist activities. From technical support to emotional support, having access to others bolstered individuals' capacities for creative work. And the social nature of learning is not reserved for kids – teachers as learners can similarly benefit from access to others (Fishman & Davis 2006).

Reflecting

« 21 » In *Mindstorms*, Papert (1980) described his vision of children as epistemologists, wherein kids use computers as an opportunity to explore their processes of thinking. Programming becomes a context for thinking about thinking, and the Logo programming language serves as something to think with.

« 22 » The activities of designing, personalizing, and sharing invite learners to ask numerous questions of themselves, of what they are doing, and of how they are think-

ing. *What do I want to create? What do I need to create it? What do I need help with? Why didn't that work as I expected it to? Who might help me? Who might I help? How might I better approach all of these questions?* These types of questions represent opportunities for kids to reflect on their activities and to think about their thinking – for kids to engage in *metacognitive* processes.

« 23 » Numerous frameworks have been proposed for articulating metacognitive processes, and several highlight the temporal dimension of metacognition – *when* the thinking about thinking takes place in relation to action. Donald Schön (1983) articulated a difference between reflection-in-action and reflection-on-action. John Bransford et al. (2000) emphasized a similar separation, drawing out self-regulation and reflection from metacognition, with the former focusing on activity planning and monitoring, and the latter focusing on assessment and evaluation of activity performance. John Flavell (1979) described metacognition as the interplay between goals (what the learner is trying to achieve), strategies (how the learner tries to achieve it), metacognitive knowledge (what the learner knows about learning), and metacognitive experiences (how the learner thinks about that knowledge in action).

« 24 » The significance of metacognition in a variety of learning and cognitive processes has long been recognized (Flavell 1979). The ideas of self-control and self-instruction described by Flavell (varyingly referred to as self-control, self-instruction, self-regulation, self-efficacy, and self-directedness) speak directly to the underlying importance of learner agency in constructionism. Albert Bandura (1997) highlighted the significance of these capacities, for supporting learning as both a life-long and life-wide activity.

> "Development of capabilities for self-directedness enables individuals not only to continue their intellectual growth beyond their formal education but to advance the nature and quality of their life pursuits. Changing realities are placing a premium on the capability for self-directed learning throughout the life span. The rapid pace of technological change and the accelerated growth of knowledge require continual upgrading of competencies if people are to survive and prosper under increasingly competitive conditions." (Bandura 1997: 227)

Supporting teachers

« 25 » A description of constructionism, no matter how detailed, is insufficient for teachers to translate the *theory* of constructionism as educational philosophy to the *practice* of constructionism in designing learning experiences. To better understand what is required to translate theory into practice, I have been studying and supporting K-12 teachers who include Scratch and the Scratch online community (http://scratch.mit.edu) in the learning experiences that they design.

« 26 » Scratch is an authoring tool that enables people to program their own interactive media projects by snapping blocks of instructions together (Resnick et al. 2009). The authoring environment is situated within an online community, where creators are able to share their projects with others (Brennan 2014; Brennan & Resnick 2013). Since Scratch's launch in May 2007, more than 9.6 million projects have been created and shared by more than 6.7 million registered members.

« 27 » Scratch draws on the traditions of the Logo programming language and community for intellectual inspiration (Brennan 2013). The intentions and aspirations for how Scratch might be employed in learning environments are grounded in Papert's vision for the types of relationships to expect and encourage between young people and computers.

> "In most contemporary educational situations where children come into contact with computers the computer is used to put children through their paces, to provide exercises of an appropriate level of difficulty, to provide feedback, and to dispense information. The computer programming the child. In the LOGO environment the relationship is reversed: The child, even at preschool ages, is in control: The child programs the computer." (Papert 1980: 19)

« 28 » But a tool itself cannot dictate how it is used in a particular environment, despite the intentions of the tool's designer (Scardamalia & Bereiter 1991). While constructionist aspirations shaped the design of Scratch, constructionism can all too easily be replaced by didacticism and technocentrism in the classroom – for example, through paint-by-numbers lessons that emphasize "mastery" of the tool at the expense of learner agency and metacognition.

« 29 » In response, my research has focused on how to support K-12 teachers working with Scratch in gaining comfort and familiarity with constructionist classroom practices and the use of technology *in support of* learning.

« 30 » The teacher professional development (PD) literature offers guidance for how to design this support. Qualities of effective PD for teachers include: extended time, moving beyond the one-shot model of teacher learning; attention to content; experiences grounded in teachers' contextual needs, such as demands of standards; access to resources and "educative materials" related to practice; encouraging reflection and critical interactions; and framing teachers as learners (Ball & Cohen 1999; Fishman, Davis & Chan 2014; Hill 2007; Hill, Beisiegel & Jacob 2013; Webster-Wright 2009; Westheimer 2008).

« 31 » Three qualities of PD that were recurrently identified in the literature as important to effective PD (particularly when teachers were engaging in new types of knowing and doing) included: (1) modeling learning, (2) engaging teachers in experiences themselves as learners, and (3) supporting social interactions among teachers. As Hilda Borko summarized:

> "There is agreement among the reports that high-quality PD incorporates processes such as modeling preferred instructional strategies, engaging teachers in active learning, and building a professional learning community. When teacher educators model instructional strategies, PD participants have the opportunity to experience these strategies as learners, and then reflect on their learning and on the effectiveness of the strategies from the perspective of teachers. This type of approach is particularly important in times of reform, when teachers frequently are being asked to teach in ways that are substantially different from how they were taught or how they learned to teach." (Borko, Jacobs & Koellner 2010: 550)

« 32 » Guided by these qualities of effective PD and responding to the needs and interests of teachers, I have been developing a model of professional development to

support teachers' understandings and explorations of constructionism with Scratch. The model, named ScratchEd, creates opportunities for communities of teachers to engage in the same designing, personalizing, sharing, and reflecting activities that are essential for young people. ScratchEd includes three primary elements – an online community, monthly face-to-face meetups, and an online workshop – and is rooted in a central assertion: teachers should have learning experiences that are comparable to their students' learning experiences, situated within a supportive community of fellow teachers. This assertion has served as a core design principle for the ScratchEd PD model, the elements of which I will now describe in more detail.

ScratchEd online community

« 33 » Although the Scratch online community has a large and active membership, it was not designed to support educators. It was designed for people who want to create and share projects, while educators are primarily concerned with helping *other* people create projects. Based on the expressed interest of K-12 teachers and motivated by the community of practice literature – a model in which teachers as learners have access to peers, shared goals, and resources (Barab, Barnett & Squire 2002; Wenger 1998) – I developed the ScratchEd site for educators (http://scratched.gse.harvard.edu).

« 34 » Teachers interested in or already actively working with Scratch can use ScratchEd to share stories, exchange resources, ask and answer questions, and find other educators. In designing the ScratchEd site, I was inspired and influenced by others' work in online communities for educators, including Tapped In (Farooq et al. 2007), KNOW (Brunvand, Fishman & Marx 2005), WIDE World (Wiske, Perkins & Spicer 2006), and Inquiry Learning Forum (Barab, MaKinster & Scheckler 2003).

« 35 » ScratchEd was publicly launched in August 2009. In the six years since its launch, more than 16 500 educators from around the world have joined the community, and have contributed more than 270 stories, 790 resources, and 5000 discussion posts. Over the past year, the site has received an average of 112 500 page views from 24 500 unique visitors per month, predominantly from the United States. The site encourages participation and contributions from members; resources and stories that illustrate and support constructionist approaches are highlighted through curation.

Scratch educator meetups

« 36 » The ScratchEd online community, although supporting teachers' needs for resources and connections, cannot provide constructionist *experiences*. I wanted to better support the experiential dimensions of teacher PD – supporting teachers in knowing what constructionist learning experiences might look like and feel like. This desire led to the development of "meetups." Scratch educator meetups derive from approaches to teacher learning that emphasize teacher agency (which places teacher thinking, ambitions, and actions at the center of the learning), rather than teacher training (which often frames the teacher-learner as passive in relation to the learning). The meetups have been inspired by participatory teacher learning models such as lesson study groups (e.g., Doig & Groves 2011; Fernandez 2010; Watanabe 2002), professional learning networks (e.g., Alderton, Brunsell & Bariexca 2011; Fulton, Doerr & Britton 2010), and EdCamps (e.g., Boule 2011; Swanson & Leanness 2012).

« 37 » The monthly meetups began in Cambridge, Massachusetts in December 2010 as a way for educators interested in Scratch to connect with their peers, support each other's learning about Scratch in a classroom setting, and share their experiences. The meetups are three hours in duration, take place on Saturday mornings, and are structured in three parts. Part one involves networking and introductions, in which people get to know each other or (depending on the number of repeat attendees) catch up. Part two consists of self-organized breakout sessions. The group, which ranges in size from 10 to 50 people, collectively negotiates different tracks of learning, focus, and activity, and then breaks out into smaller groups to pursue those interests. Part three, which occurs over lunch, involves reporting out from the breakout groups, sharing experiences in a show & tell format, and general group updates and announcements.

Creative Computing Online Workshop

« 38 » ScratchEd meetups are geographically constrained, accessible only to those in and around Boston. In response, with support from Google's CS4HS program and motivated by curiosity to explore large-scale online learning environments as sites of constructionist learning experiences, I led the development of the Creative Computing Online Workshop (CCOW), an open online learning experience. The workshop was built using Google's Course Builder platform, which provided the infrastructure for creating an online course.

« 39 » CCOW (http://creative-computing.appspot.com) was organized as an experience for teachers to learn about Scratch, both as a tool and as an approach to learning. CCOW was hosted for six weeks, from June 3 until July 12, 2013. Approximately 2100 people from all around the world enrolled in the workshop, with 51% of those enrolled indicating that they intended to participate beyond "just browsing."

« 40 » During the workshop, participants engaged in a variety of activities. They created Scratch projects, working with the latest version of Scratch (Scratch 2.0), from focused debugging challenges to more open-ended design explorations. They maintained online design journals that served as a record of and reflection on their participation throughout the workshop. They defined and pursued independent learning projects, such as designing curriculum, hosting workshops for kids, and exploring the connections between programming and art. They interacted with workshop colleagues through comments on design journals and discussions in the course's online forums. Over the six weeks of the workshop, CCOW participants watched workshop videos 24 000 times, created 4700 Scratch projects, wrote 3500 discussion posts, and shared 180 final projects.

Negotiating tensions

« 41 » Having worked on the development of the ScratchEd model to support teachers' explorations and experiences with constructionist approaches in the classroom for the past several years, I am often asked, "What lessons have you learned from your

work?" I have come to appreciate that my experiences and understandings are more aptly described as "tensions negotiated" than "lessons learned." These tensions are developed from thematic coding of my design notes, memos on intentions for and experiences with the designs described in the previous section, as well as interview data from teachers who variously participated in the online community, meetups, and online course. They are grounded in the complexities that arose from trying to support teachers' experiences with designing, personalizing, sharing, and reflecting within a professional development learning context. In this section, I describe five of the most pressing tensions, illustrated with examples from my experiences as a designer of the ScratchEd model of professional development for K-12 teachers.

Tension between tool and learning

« 42 » Constructionist approaches to learning emphasize the importance of culture over content and learning over tool, and are well aligned with aspirations to disrupt technocentrism in the classroom. All three elements of the ScratchEd PD model prioritize pedagogical knowledge over content knowledge. That is, the online community, the meetups, and the online workshop emphasize thinking about constructionist approaches to learning over thinking about the mechanics of Scratch as tool or thinking about particular computer science concepts. But emphasis on content can also be important to supporting teachers' learning and development (Fishman, Davis & Chan 2014; Hill, Beisiegel & Jacob 2013), and for some teachers, a lack of content knowledge can undermine confidence, discouraging them from using Scratch with their students. A balance must therefore be achieved between knowledge about the tool and understanding of how to engage in creative design activities, using the computer for personal expression and problem solving.

« 43 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 44 » A wide range of resources are posted by my research team and by members of the ScratchEd community. We curate resources for teachers that strike a balance between tool and learning, promoting them to have greater visibility within the online community.

Meetups

« 45 » The participatory nature of the meetups invites a wide range of potential topics and formats. At the beginning of each meetup, we provide examples of potential breakout sessions (which range from more tool-centric, to more learning-centric, and everything in between). Seeding the collective brainstorming with examples for the breakout sessions helps manage the balance.

Online workshop

« 46 » Reflective journaling is a critical component of participation in the online workshop. Teachers' design journals are framed as a place to reflect on artifacts and activities, with prompts encouraging them to question the implications for their teaching practice and students' learning.

Tension between direction and discovery

« 47 » Teacher-learners (and all learners, more generally) flourish when they are invited and supported to take ownership of and responsibility for learning goals, instead of primarily following the ambitions and direction of others. But in order to achieve their goals, learners require access to resources to support the pursuit of their pathways (Fishman, Davis & Chan 2014). In response, PD designers need to make experiences and resources available that are appropriately accessible (in format and complexity) and appropriately timed (in duration and pacing) for the learner. In doing so, the PD designers negotiate a central tension between direction (providing resources in advance, anticipating and steering learner needs) and discovery (making resources available when they are needed, in response to learner needs).

« 48 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 49 » All of the stories, resources, and forums are asynchronously available to members through various search mechanisms for self-directed support. For those who need more curated, externally-directed support, such as novices, this support is available in the form of landing pages for beginners.

Meetups

« 50 » The informal nature of the meetups makes it possible for teachers to participate as needed throughout the year, and the content of each meetup is directed by the participants themselves. In the moment, participants make decisions about how directed or discovery-oriented to make each breakout session.

Online workshop

« 51 » The online workshop is structured as a collection of flexible, curated pathways of resources, within a directed six-week participation window. After the synchronous window, the resources of the online workshop (e.g., activity descriptions, tutorial videos) continue to be available for self-directed support.

Tension between individual and group

« 52 » As described in "Defining constructionism," learning is not an individual process – learners can benefit from being connected with others (Brown, Collins & Duguid 1989; Lave & Wenger 1991; Rogoff 1994). These connections can take different forms, with others potentially serving key roles as advisors (e.g., providing advice for challenges), as collaborators (e.g., jointly pursuing a learning goal), as audience (e.g., showing appreciation for creative work), and/or as advisees (e.g., someone with whom to share one's understanding). Individuals unfamiliar with social learning, however, may resist these opportunities, seeing them as not aligned with or even antithetical to their own interests and goals. For the PD designer, cultivating connections between learners and others involves (at least) two components: (1) helping teachers identify potential connections (i.e., matchmaking), and (2) supporting positive interactions within those connections (i.e., respectful, productive, and mutually beneficial). Designers can introduce structures that support connection-making processes (e.g., introducing learners to those who

have compatible and complementary interests, or grouping learners with those who have divergent interests as a way to broaden learners' perspectives).

« 53 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 54 » Members of the online community have a personal profile, which offers information about their background and interests. People can explore profiles through a faceted search mechanism. For example, displaying all members who teach secondary-school children, live in Europe, focus on mathematics education, and speak Dutch. This helps members view the larger community of 16K+ members as collections of smaller interest groups, hopefully minimizing feelings of being lost in the larger community.

Meetups

« 55 » A portion of each meetup is dedicated to networking and collaborative schedule-making to accommodate a wide range of interests and to support connections among participants. Exploring those interests is further supported through the breakout sessions, where participants are encouraged to freely move between sessions to follow their interests and needs.

Online workshop

« 56 » Teacher participants were paired with other workshop participants to provide comments and feedback on each other's projects and design journals. We used feedback protocols as a mechanism for encouraging critical and respectful interactions.

Tension between expert and novice

« 57 » Closely related to the tension between the individual and the group is the tension between individuals within a group as they take on roles of "expert" and "novice." Our work has involved teachers with a range of backgrounds – from teachers who have extensive classroom experience to those who are just starting their practice, teachers who have long-adopted constructionist practices to those with more didactic or teacher-centric approaches, and teachers who have extensive experience with computer science and Scratch to those who describe themselves as terrified by computers. Across these dimensions, there are multiple notions of who is an "expert" and who is a "novice." But while it can be beneficial to have participants with a broad variety of expertise, relying too extensively on the expertise of participants can be problematic. First, in participatory models of learning, those with greater expertise or confidence can be denied opportunities to extend their own learning. Second, expertise in one aspect of practice does not imply expertise across all aspects of practice. Those cast as "experts" may unintentionally encourage "incongruent adaptations" (Lin & Fishman 2009) or "lethal mutations" (Brown & Campione 1996) of constructionist practices. Accordingly, PD designers should consider how to disrupt conventional notions of expertise and invite broad participation.

« 58 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 59 » In the early days of the discussion forums, we were careful not to respond too quickly to questions. By creating the space for others to respond, my research team's anticipated expertise was supplanted by the expertise of community members.

Meetups

« 60 » The breakout sessions are explicitly framed as not didactic. Breakout sessions should not be lectures; they are about mutual exploration and sharing. Setting this cultural expectation disrupted ideas about who was the "expert" and who was the "learner," creating the possibility for more fluid notions and performances of expertise.

Online workshop

« 61 » Participants in the workshop were encouraged to make all of their work public, whether in the form of their Scratch media projects or their reflective journal writing. This culture of openness made it possible for all participants to peek into and learn from others' processes. Novices learned from the more sophisticated approaches of those more expert; experts were exposed to a wider range of implementation strategies.

Tension between actual and aspirational

« 62 » In many ways, constructionist learning experiences are fundamentally at odds with the lived reality of K-12 education. The lack of resources, lack of time, lack of administrative support, lack of meaningful metrics for assessment and evaluation, and even a lack of interest from learners, can all contribute to an (at times) overwhelming sense of challenge. A tension exists for PD designers, then, between the actual and the aspirational, to determine what is feasible given current constraints and what might be imagined for the future(s) of learning. Inherent to the role of a PD designer is to offer a sense of the possible, to share what learning could be like. This stance often conflicts with barriers perceived or imagined by teacher participants, and will involve sincerely engaging with concerns – the collection of "but…" statements, such as "I'd like to do that, but…," "That seems interesting, but…," or "I see how you could do that, but…"

« 63 » Within the elements of the ScratchEd model, I negotiate this tension in different ways.

Online community

« 64 » The *Stories* section of ScratchEd most directly contributes to this balance. In the initial days of the online community, we interviewed teachers who were working with Scratch in the classroom and wrote stories about their activities, highlighting the opportunities and acknowledging the challenges. These stories illustrate the possible, while respecting the lived reality of teachers' experiences.

Meetups

« 65 » In co-designing the breakout sessions, teachers have the opportunity to incorporate the daily contextual demands of their practice into session activities. By engaging with colleagues in critical and reflective discourse about their experiences, teachers are able to surface their concerns and challenges, while making plans and taking actions for change and reform.

Online workshop

« 66 » In addition to the reflective design journal, workshop participants defined and pursued a self-directed project. The pur-

KAREN BRENNAN
is an assistant professor at Harvard University in the Graduate School of Education. Her research is primarily concerned with the ways in which learning environments – in and out of school, online and face-to-face – can be designed to support young people's development as computational creators. Her research and teaching activities focus on constructionist approaches to designing learning environments – encouraging learning through designing, personalizing, sharing, and reflecting, and maximizing learner agency. Before joining HGSE, Brennan completed her PhD in Media Arts and Sciences at the MIT Media Lab, as well as an MA in curriculum studies, BEd in computer science and mathematics, and BSc in computer science and mathematics at the University of British Columbia.

pose of the project was to create a space for participants to plan a change to their teaching practice. The range of projects that the teachers created reflected the varying contextual demands that they were negotiating.

Beyond technocentrism

« 67 » While the ScratchEd model of professional development represents a specific example of how to support K-12 teachers who wish to incorporate technology in the service of learning, I would argue that the tensions I experienced in supporting teachers are not specific to Scratch, and can serve as a more general model for PD designers to scrutinize and critique.

« 68 » The specific tensions discussed in this work are particularly salient for constructivist and constructionist approaches to learning. Constructivist approaches to PD (which, as Hilda Borko, Jennifer Jacobs, and Karen Koellner (2010) argued, represent the direction that teacher professional development is – or at least should be – headed in, given what we know about learning more generally from educational psychology and the learning sciences) and constructionist approaches to PD, invite the type of "disequilibrium" (Ball & Cohen 1999: 14) necessary for teacher learning. Each of the five tensions presented here highlights some dimension of the disequilibrium present in constructivist/constructionist learning environments: the role of content, the role of learner autonomy and agency, the situated and social role of learning, the role of expertise, and the role of contextual demands.

« 69 » In the inaugural issue of *Constructivist Foundations*, in response to the question "What is constructivism?," Alexander Riegler outlined ten points of a "constructivist program." The sixth point in his program was a move "from the world that consists of *matter* to the world that consists of *what matters*" (Riegler 2005: 4). This move from *matter* to *what matters* is also central to a similarly framed "constructionist program." Papert's *Computer Criticism vs. Technocentric Thinking* illustrates this shift from matter to what matters, from computer to learning culture.

> "The context for human development is always a culture, never an isolated technology. In the presence of computers, cultures might change and with them people's ways of learning and thinking. But if you want to understand (or influence) the change, you have to center your attention on the culture – not on the computer." (Papert 1987: 23)

« 70 » But equally central to a constructionist approach is the return trajectory, the interplay between matter and what matters. The "matter" (i.e., the technology) makes possible the "what matters," enabling learners to build, make, create, and play, externalizing and expressing their ideas, connecting learners to the world beyond themselves and their classrooms, connecting learners to each other, and forming traces of learning that can serve as the basis of metacognitive activities. In a constructionist learning environment, the "what matters" depends on "matter" in an important way as a means of engaging in the work of design and construction.

« 71 » Designing for this interplay between matter and what matters in a constructionist learning environment necessitates more than following a checklist of opportunities to include for learners, whether those learners are teachers in a PD context or students in a K-12 classroom. Creating opportunities for learners to design, personalize, share, and reflect as part of their regular learning experiences involves negotiating the tensions and complexities of constructionist learning environments, engaging in careful observation and interrogation of activities, people, resources, and roles. It is within this complexity that learning can flourish, beyond technocentrism.

Acknowledgements

The author wishes to thank the guest editors for their encouragement and persistence, as well as the OPC respondents for their thought-provoking comments. This material is based on work supported by the National Science Foundation under grant no. 1019396, by the Code-to-Learn Foundation, and by Google. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF, the Code-to-Learn Foundation, or Google.

Received: 22 February 2015
Accepted: 1 June 2015

Open Peer Commentaries

on Karen Brennan's "Beyond Technocentrism"

Embedding Technology in Pedagogy

Hugh Gash
St Patrick's College, Ireland
hugh.gash/at/spd.dcu.ie

Thomas McCloughlin
St Patrick's College, Ireland
tom.mccloughlin/at/spd.dcu.ie

> Upshot • Brennan describes strategies designed to help teachers use Scratch in their classrooms, emphasising interfaces between the tool and its users, between users and between hope and happening. Previous work with similar aims identified apparently significant cultural approaches to initiating constructionist practice. Questions arise about the development of practice from technocentric to pedagogic over time that may have some answers in the data accumulated.

« 1 » At present we are part of a European Union-funded project (TEALEAF) designed to introduce "serious games" in the context of science education to teachers in five countries (the Czech Republic, France, Ireland, Slovenia, and Spain) with a view to teaching and learning about biodiversity through the medium of Scratch-based apps. Our project is based in a previous approach that sought to promote constructivist practices in primary and secondary classrooms in teaching science. To assess these differences we used the Constructivist Learning Environment Survey (CLES), designed by Peter Taylor and Barry Fraser and others (1997). We found significant differences apparent in teachers' approaches in each country and at each level of schooling within each country (Groupe Interuniversitaire Projet Sophia 2009; Gash & McCloughlin 2010). We believe these data are useful in thinking about Karen Brennan's work, particularly as we strove to employ apps as a means to learn science and challenge technocentrism in a different way.

« 2 » Brennan has identified five "interfaces" as crucial in helping the teachers she worked with to use the Scratch tool. These are acutely in tune with the difficulties of introducing new technologies in classrooms and sensitive to the ways both teachers and projects work. Two of these, the interfaces between "tool and learning" and between "expert and novice" offer an opening to difficulties teachers may have in changing their ways of working, ways that may depend on their beliefs about teaching (Sharkey 2014). These beliefs are related to the ways teachers teach and are reflected in their attitudes to constructivist teaching activities.

« 3 » In our previous European Union-funded project (SOPHIA), we found that Irish primary teachers, in contrast to secondary teachers, were more attuned to the personal relevance of learning and the importance of students communicating about what they know (Gash & McCloughlin 2010). These are features of constructivist teaching that vary within the teaching profession and that seem crucial in implementing constructionist approaches. More use of methods requiring constructionist outcomes might facilitate this dimension of constructivist practice. Was this a dimension that varied in the author's sample, or was it so necessary for the methods used that it was taken for granted and obscured?

« 4 » The five interfaces are related to implementing Scratch technology in classrooms. So we would like to ask Brennan how the importance of these interfaces varies over time? We assume that the tension between tools and learning is quickly resolved, and that ahead of time and just-in-time issues are resolved by teachers as they become more experienced. However, group relations and expert novice relations intuitively seem less easy to resolve? Was this the case?

« 5 » In another study, Deirdre Butler (2004), working with the former Media Lab Europe in Dublin, believed that offering teachers challenges with digital technology like those offered to children would provide teachers with insights into ways to structure learning experiences for children. Butler found that it was helpful to categorize teachers on two categories: (a) fluency with digital technologies (high and low) and (b) how the teachers conceptualized learning (instructionism and constructionism). These were dimensions on which Butler could place particular teachers and seemed comparatively stable dimensions of a teacher's approach. They seem to relate closely to the issues implied in the tensions between "tool and learning," "expert and novice" and "actual and aspirational." However, Butler's experience was that they were relatively stable dimensions of a teacher's approach. In Brennan's data, are there insights into ways to help teachers change their approach? We also worked with Media Lab Europe and explored the tension between two biological environments: the "virtual" and the "real" (Cherubini, Gash & McCloughlin 2008). However, such a tension appears so great for some teachers that they shy away from digital technology altogether.

« 6 » Information and communications technological pedagogical content knowledge (ICT-TPCK) as a concept has been developed by Charoula Angeli and Nicos Valanides as:

http://www.univie.ac.at/constructivism/journal/10/3/289.brennan

"the ways knowledge about tools and their affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners or difficult to be represented by teachers can be transformed and taught more effectively with technology in ways that signify its added value." (Angeli & Valanides 2009: 154)

Punya Mishra and Matthew Koehler (2006) examined three key components of ICT-TPCK, namely:

1 | competing resources; and
2 | lack of confidence both in the science content *and*
3 | the competency in using digital learning.

These are often too disparate to synthesize, since synthesis requires components that coalesce at some point, so consideration of the stability of the dimensions of a teacher's approach is prescient since it was a content focussed study – learning about science through technology. However, for Brennan, technology is the goal of the learning itself and this might also be considered as technocentric, except that Brennan uses Scratch as an affordance to higher-order thinking processes such as "creating," and "middle-order" thinking processes involved in social interaction. The three experiments outlined by Brennan were designed to disrupt technocentrism, but how successful was that?

« 7 » Brennan's work could be viewed within the framework of ICT-TPCK, and we particularly support her approach of focussing on pedagogical knowledge as opposed to content knowledge. However, we would suggest that there is a close relationship between the two and teachers may on the one hand find dealing with the pedagogical issues simpler, whilst their externally imposed learning outcomes may require an emphasis on content. Her work on challenging "technocentrism" is prescient since the constructivist is concerned with overall cognitive and emotional development not governed by an external objective reality. Technology can sometimes become such a reality, and in doing so, the user becomes the servant, and technology becomes the beginning, middle and end of learning.

Acknowledgements

This project was funded with support from the European Commission. SOPHIA COMENIUS Project 128958-CP-1-2006-1-FR-COMENIUS-C2, TEALEAF ERASMUS-PLUS Project 2014-FR01-KA201-008559. *Disclaimer*: The content of the document reflects the views of the authors only, and the Commission cannot be held responsible for any use that may be made of the information contained therein.

Hugh Gash obtained his doctorate at State University at Buffalo in 1974. He was a post-doctoral researcher at the University of Georgia with Charles Smock and then worked at St. Patrick's College Dublin until 2010. Gash is a member of the International Institute for Advanced Studies in Systems Research and Cybernetics. He has published extensively on educational applications of constructivism, details of which may be found on his website, http://staff.spd.dcu.ie/gashh/

Thomas McCloughlin is a "committed radical constructivist," biologist and lecturer in education at St. Patrick's College, Dublin, following a career as a secondary-school science and mathematics teacher.

Received: 20 May 2015
Accepted: 15 June 2015

Changing Teacher Beliefs: Moving towards Constructionism

Carina Girvan
Cardiff University, UK
girvanc/at/cardiff.ac.uk

> Upshot • If we are to move beyond technocentricism, we need not only to equip teachers with pedagogical approaches but to support a change in their beliefs, values and assumptions. While factors such as assessment practices and institutional norms can limit the impact of professional development by considering the ways in which teachers form their teacher-identity and the factors that can motivate change, we can begin to develop approaches to professional development that can have lasting impact on teachers and their learners.

« 1 » Teacher-role identity is influenced by the experiences that teachers have had as learners themselves. Many of our current teachers experienced a technocentric integration of technology into their own education and so this may be seen to be an acceptable norm. In asking how we can defend against technocentricism, Karen Brennan suggests that an extreme approach is to exclude digital technologies from core classroom experiences. Yet, unfortunately, this is not an uncommon practice. There can be a tendency to treat ICT or computing as discrete subjects, taught in silos by experts, particularly in secondary-level education. This is emphasised by the allocation of a specific timeslot in the timetable and an expectation that the "skills" are learnt there. This is just one way in which the "invisible curriculum" can be seen not only to influence learning but also teaching. There can be an expectation that students will have developed the skills required, either from these discrete classes or from their use of technology at home. This can result in a belief that teachers need not integrate the use of technology into learner-centred approaches as that "Key Skill" has been covered by someone else (in much the same way as numeracy and literacy skills are assumed to be covered in maths and English classes). Thus, in the classroom, ICT is used for ICT's sake (Bertam & Waldrip 2013), in a teacher-centred approach and to "tick-off" a requirement. On the other hand, it can also result in an assumption that students are able to use the technologies teachers ask them to, both effectively for learning and responsibly, when they may never have encountered them, least of all used them to learn *with* or *through*. Thus the teacher may find themselves frustrated at the lack of student progress on specific tasks, resorting to technocentric teaching of skills or avoidance of technology altogether.

« 2 » One approach to resolving technocentric teaching is to restructure the school day, providing support for teachers to collaborate, teach in teams and develop interdisciplinary lessons. This is used in the Bridge21 model for teaching and learning (Conneely et al. 2015), which emphasises the use of technology to mediate learning but is not dependent upon it. In a Bridge21 lesson, learners collaborate in teams in

which technical skills are developed alongside subject-specific knowledge. There is no expectation that learners will have separate ICT "training" to develop skills. Rather, skills are developed as required to facilitate the completion of projects. Importantly, the technical skills, along with developing knowledge and understanding, are held at the level of the team, not requiring any one individual to know "how-to" or for the whole team to gain, necessarily, a specific skill.

« 3 » Maria Daskolia, Chronis Kynigos and Katerina Makri (this issue) present an excellent example of some of the complexity that surrounds the use of technology to support learning through collaborative constructionist activities. The article highlights that the technology had to be learned and learners skills in the use of specific applications have the potential to constrain the final digital story that learners created. However, an interesting question remains – did the lack of these skills become a barrier to learning? As Brennan suggest, a technocentric view of technology in the classroom would lead to the answer "yes." However in this constructionist learning activity, learners were free to choose the technologies they felt would enable them to demonstrate their understanding and create their digital story. While a lack of technical skills may have limited their creative vision, there is no evidence to suggest it limited learning.

« 4 » So how can we best support teachers through professional development to move away from technocentric approaches to the use of technology in the classroom? It is essential that in any professional development programme, we address the underpinning ideas, beliefs and values of teachers, which Robin Alexander (2008) describes as informing, justifying and sustaining their existing practices. Pre-existing teacher-role identity (Knowles 1992) influences these ideas, beliefs and values, which are reinforced by pressures from national assessments and cultures of compliance within schools. These factors can limit the effectiveness of any new initiative and limit the potential for teachers to develop their practice beyond existing norms.

« 5 » Caroline Daly, Norbert Pachler and Caroline Pelletier (2009), in their review of CPD in ICT for the UK agency BECTA, recognise the importance of teachers taking personal responsibility for their learning and for CPD to be flexible enough to support personal learning journeys. Initial education and professional development courses can be seen to present an idealistic view of teaching and learning that does not always take into consideration curriculum and assessment pressures or the normalising effect of individual institutions. One approach that allows us to address this, and resonates with Brennan's article, is that of TeachMeets, which provide opportunities for professional development through a network of teachers who meet, share and discuss their practice, potentially alleviating these concerns. As a route to understanding the practices of others, this also has the potential to influence teacher-role identity.

« 6 » A final factor that Brennan and others may wish to consider in future work is the influence of student outcomes on teachers' ideas, beliefs and values. Thomas Guskey (2022) identifies positive changes in student outcomes as one motivating factor for teachers to change their own practice. While this may be the ultimate aim of CPD, I suggest that we should engage this motivational factor early on in the professional development process, demonstrating positive outcomes for students' learning at the beginning of the CPD process. This needs to be facilitated in an authentic manner that resonates with teachers' professional practice, is contextually sensitive and ideally provides an opportunity for teachers to observe and reflect upon the activities and outcomes for their learners without the distraction of managing learning.

Carina Girvan is a lecturer in the School of Social Sciences at Cardiff University. Her research focuses on the innovative use of existing and new technologies in education, as well as teacher professional development and emerging ethical issues in the use of new technologies in education.

Received: 8 June 2015
Accepted: 18 June 2015

Embedding Inquiry and Workplace in a Constructionist Approach to Mathematics and Science Teachers' Education

Giorgos Psycharis
University of Athens, Greece
gpsych/at/math.uoa.gr

> Upshot · Brennan describes ways by which teachers can be supported to bypass a technocentric view of learning with technology in the classroom, from a constructionist perspective. She reports on the development of a corresponding model of professional development (PD) by describing the elements of the model and its design principles as well as the tensions that arose while trying to support teachers' explorations and experiences in the classroom. Questions arise about the potential of the model to be exploited to address issues underlying teachers' professional development in different contexts.

« 1 » My choice here is to explore further Karen Brennan's implication that the tensions she needed to negotiate with the teachers are not specific to her study and "can serve as a more general model for PD designers to scrutinize and critique" (structured abstract). I will try to link my experience as a teacher educator with Brennan's work, based on my current involvement in the European Union-funded project "Mathematics and Science in Life" (Mascil). It aims to promote a widespread use of inquiry-based mathematics and science teaching in primary and secondary schools through the connection between inquiry-based learning (IBL) and the world of work (WoW). The project runs PD courses of different types (e.g., face-to-face, e-learning) in all participating (13 in total) European countries. It provides an initial body of generic classroom tasks and a document containing guidelines for teachers to develop their own tasks by connecting IBL and workplace contexts.

« 2 » A distinctive feature of implementation in Mascil is its systemic character in terms of involving different institutional

and social contexts where context-specific interventions are planned and learning communities of teachers are established (e.g., groups of teachers from a single school or neighboring schools working in the same educational level). The teachers experience IBL themselves through their involvement in iterative cycles of design-implementation-reflection. To ensure widespread participation, the project adopts a scaling-up approach aiming to engage a large number of teachers in PD activities through a pyramid model based on the use of multipliers. Being one of the multipliers in the current year, my objective was to engage a group of 12 mathematics and science teachers in integrating technology, IBL and WoW in their designs and practice under a broadly constructionist perspective. It was expected that this integration would be facilitated through the teachers' engagement in adapting Mascil tasks or developing their own in the same spirit, based on authentic situations of workplace mathematics and/or science. The teachers were organized in a learning community that met regularly in face-to-face meetings (i.e., before and after implementations) and also had the choice to communicate asynchronously through a teachers' communication platform. Below, I use Brennan's categorization to describe briefly the tensions that I had to address/negotiate in the context of the community. I also highlight emergent implications /questions for in-service teachers' mathematics and science education.

Tension between tool and learning

« 3 » In developing their designs, the participating teachers faced the challenge of addressing the need to have a balance between a focus on the use of tools in the context of specific tasks (e.g., modeling the construction of a parking) and the students' learning of mathematics. This tension was resolved in the community through reflection on the nature of the emergent mathematical concepts in different types of designs (e.g., situation specific, open-ended) aiming to bridge school and out-of-school mathematics.

Tension between direction and discovery

« 4 » The tension between direction and discovery in Mascil was primarily based on the opposition between guided learning and IBL (Artigue & Blomhøj 2013). Since most of the teachers chose to develop their own tasks, they faced the dilemma of how much "exploration" could be integrated in their designs. One success that emerged in the evolution of implementation was that the newly developed tasks by the teachers were progressively less structured and more inquiry oriented. The factors that seemed to support this development were related to particular features of the PD courses such as the discussion of the IBL features of specific tasks as well as the sharing of successful implementations during the reflective sessions of the group.

Tension between individual and group

« 5 » The challenge of collaboration constituted a distinct feature of Mascil. Teachers were encouraged to develop their designs collaboratively so as to have a common ground for reflection after the classroom implementations. One emerging tension – that could probably be used to define new category or sub-category of tensions – concerned the teachers' reluctance to collaborate with colleagues that had a different discipline from their own (i.e., mathematics teachers vs. science teachers). This tension was resolved in the PD meetings by creating a space of making connections between pieces of content knowledge involved in mathematics and science tasks and reflecting on the potential of these connections for students' learning.

Tensions between expert and novice

« 6 » Most of the participating teachers in Mascil were experienced teachers. However, extensive classroom experience was not a condition adequate for considering these teachers as "experts." For instance, some of them did not have a "constructionist background," or they were never engaged in designing a classroom innovation. Thus, it was necessary for me to re-conceptualize the meaning of the opposition expert-novice in relation to the teachers' "readiness" to adopt an IBL approach in their lesson, as a first step in the direction of recognizing the learning potential of a subsequent constructionist experience in their classroom.

Tension between actual and aspirational

« 7 » Integration of WoW in classroom tasks constitutes an innovative challenge for teachers (Wake 2014; Hoyles, Noss, Kent & Bakker 2010). There are a number of emerging tensions underlying the distance between actual and aspirational in teachers' designs and implementations in Mascil. At the beginning of PD courses, the majority of teachers found it difficult to recognize the potential of integrating the WoW in their educational activities, invoking constraints posed by the curriculum and the available teaching time. However, the reflective practices cultivated within the group seemed to support them to appreciate gradually the potential value of integrating the WoW in their classroom teaching.

« 8 » The above description of the tensions I experienced when trying to support mathematics and science teachers to embed IBL and workplace in their teaching under a broadly constructionist approach indicates that the Brennan's model offers us a useful lens to address the tensions inherent in the process of educating teachers to adopt constructivist/constructionist approaches in different PD contexts. A number of questions can be raised to challenge her to extend her work. What structures can support teachers to engage in designing and implementing classroom innovations under a constructivist/constructionist approach? What is the role of other resources (e.g., tasks) or contexts (e.g., workplace) that might support teachers' constructionist approaches in the classroom? What are the features of the teachers' learning communities and the practices in which they are engaged (e.g., types of inquiry) that can support their explorations and experiences with constructionist approaches in the classroom? How do these features/practices influence the nature of the emerging tensions in teachers' PD activities? How can these tensions can be negotiated by the teacher educators so as to enhance the teachers' professional learning?

Acknowledgements

The project Mascil – Mathematics and Science in Life, http://www.mascil-project.eu – received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 320693.

Giorgos Psycharis is Lecturer in Mathematics Education in the Department of Mathematics at the National and Kapodistrian University of Athens, Greece. His fields of interest include the design of learning environments for mathematics involving the use of digital technologies (emphasis on the role of context and tools in the classroom setting) and teacher education in pre-service and in-service levels.

Received: 15 June 2015
Accepted: 16 June 2015

Author's Response:
The Critical Context of Teacher Attitudes and Beliefs

Karen Brennan

> Upshot • The OPC responses aptly identified numerous factors teachers encounter that can impede changes in pedagogical practice in the classroom. Although some of these factors are external, beyond a teacher's control, I discuss one internal factor – a teacher's attitudes and beliefs about their role and the learners they support – that was raised in the responses.

A tale of two teachers

« 1 » Several years ago, I co-facilitated an introductory Scratch workshop, hosted at a regional technology conference for teachers. After the 20 participants arrived, we showed them three or four projects created by young learners, to give them a sense of what might be possible to create with Scratch. Then, we transitioned to hands-on time for the teachers. The activity was *Pass-It-On*, in which the teachers collaboratively worked on a project connected to the theme of Halloween (which happened to be on the upcoming weekend). We started the activity by modeling – this enabled us to introduce the basic mechanisms of Scratch (e.g., snapping blocks together, running the program), giving participants what we hoped was enough scaffolding to get started. After the modeling, pairs of teachers had 15 minutes to start their stories. After 15 minutes elapsed, each pair stood up, left their computer, and moved to another computer, where they continued the story that they found at the new computer. After another 15 minutes, the pairs rotated again, and then eventually returned to their original computers to see how the other sets of partners had modified their initial creations. Participants were usually surprised and delighted by the evolution of the projects in their absence. (Although some people were sensitive about changes to their original vision.)

« 2 » We asked participants to talk about their experiences with the activity and how such an activity might work in their own classrooms. One teacher expressed doubt about adding the activity into her lessons. "This was great for me, but I couldn't let my students get started this way. I'd need to show them more, right? I couldn't just let them play, right?" She looked around the room at the other teachers for confirmation.

« 3 » A teacher on the other side of the room quickly jumped in:

> "I don't think you need to be so structured. I've been using Scratch for about three years. I started using the Scratch cards with kids because I thought that was a good way to introduce it to them. So I asked them to go through each of the twelve cards before they could start their own project. But that was a big mistake because they got very bored with those cards immediately. Today, what I do with the cards is that I leave them on the table and the kids know the cards are there. They can look for a particular card when they need it. The kids want to be able to just work on their projects and be a little freer."

« 4 » Another teacher, sitting at the back of the room, forcefully raised her arm, while shaking her head:

> "I teach it a different way – I don't let them go and do it, because they just sit there and say, 'I don't know how to make the cat move!' So, I lead them through Scratch step-by-step. It takes me three or four weeks to go through all that. Because if I just ask them to make something, some of the kids – some of them are creative and do produce something – but a lot of them just make something dancing on a screen saying, 'Hi! Hi! Hi! Hi! Oh, you're cool! Hi! Hi!'"

Teacher attitudes and beliefs as context

« 5 » I was reminded of this experience as I read the responses from **Hugh Gash** and **Thomas McCloughlin**, **Carina Girvan**, and **Giorgos Psycharis**. All three responses raised important questions about the significance of context in supporting (or suppressing) constructionist approaches to learning in the classroom. In some cases, these questions focused on external factors – issues and constraints that individual teachers are subjected to as part of their lived contextual experience, but essentially beyond their control. For example, **Girvan** highlighted the constraining function that national assessments can exert on teachers experimenting with new pedagogical practices.

« 6 » Equally important, as the responses argued, a teacher's own attitudes and beliefs play a critical role in directing and shaping their interest, willingness, and ability to include constructionist approaches to learning in the classroom. This is what reminded me of the workshop experience. These two teachers – who were contextually similar, subjected to the same geographic, socioeconomic, grade-level, subject-area, and policy factors – differed primarily in their attitudes and beliefs about their role as teacher and the role and capacities of their students, a type of "internal" context.

« 7 » Too often, professional learning experiences are designed around a facile compliance model – one in which teachers have an experience that they are then expected, without attention or sensitivity to contextual variations, to execute faithfully in the classroom (Lieberman & Pointer Mace 2008). In fact, there is significant complexity in translating professional learning experiences into practice as teachers negotiate external and internal contextual factors (Windschitl 2002). And, although both sets of factors are important, given the limited control that most teachers have over external factors, I argue that it is critically important to engage the internal contextual factors in teachers' professional learning experiences.

« 8 » But what might this engagement look like? In the vision for professional learn-

ing that I described in my article, the teacher learns through experience, an approach aligned with similar endeavors described in the three OPCs and in the broader literature about teacher learning. In the specific case of ScratchEd, in which I study and support teacher professional learning as a means to support constructionism in the classroom, the teacher learning is itself constructionist, emphasizing learning activities of designing, personalizing, sharing, and reflecting. In this approach, the work of surfacing teacher attitudes and beliefs can cut across all four of these activities, but particularly in reflection. Reflection should invite teachers to consider their experiences within the professional learning setting, but, equally importantly, to engage in self-reflective processes, creating opportunities to consider their own preconceptions, attitudes, assumptions, and beliefs. Documentation can serve as a critical component of this self-reflective process – through personal journaling, interviews, or portfolios. These forms of documentation can trace the evolution of attitudes and beliefs over time, making the tacit explicit, and making change possible.

Received: 18 June 2015
Accepted: 26 June 2015

Combined References

Ackermann E. (1996) Perspective-taking and object construction: Two keys to learning. In: Kafai Y. B. & Resnick M. (eds.) Constructionism in practice: Designing, thinking, and learning in a digital world. Lawrence Erlbaum, New Jersey: 25–35.

Alderton E., Brunsell E. & Bariexca D. (2011) The end of isolation. Journal of Online Learning and Teaching 7(3): 1–14.

Alexander R. (2008) pedagogy, curriculum and culture. In: Murphy P., Hall K. & Soler J. (eds.) Pedagogy and practice: Culture and identities. Sage, London: 3–27.

Angeli C. & Valanides N. (2009) Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). Computers and Education 52: 154–168.

Arigue M. & Blomhøj M. (2013) Conceptualizing inquiry-based education in mathematics. ZDM – The International Journal on Mathematics Education 45: 797–810.

Ball D. L. & Cohen D. K. (1999) Developing practice, developing practitioners: Toward a practice-based theory of professional education. In: Sykes G. & Darling-Hammond L. (eds.) Teaching as the learning profession: Handbook of policy and practice. Jossey Bass, San Francisco: 3–32.

Bandura A. (1997) Self-efficacy: The exercise of control. W. H. Freeman, New York.

Barab S. A., Barnett M. & Squire K. (2002) Developing an empirical account of a community of practice: Characterizing the essential tensions. Journal of the Learning Sciences 11(4): 489–542.

Barab S. A., MaKinster J. G. & Scheckler R. (2003) Designing system dualities: Characterizing a web-supported professional development community. The Information Society 19(3): 237–256.

Bertram A. & Waldrip B. (2013) ICT for ICT's sake: Secondary teachers' views on technology as a tool for teaching and learning. Australian Educational Computing 28(1): 61–70.

Borko H. (2004) Professional development and teacher learning: Mapping the terrain. Educational Researcher 33(8): 3–15.

Borko H., Jacobs J. & Koellner K. (2010) Contemporary approaches to teacher professional development. In: Peterson P., Baker E. & McGaw G. (eds.) International encyclopedia of education. Third edition.. Elsevier, Oxford: 548–556.

Boule M. (2011) Mob rule learning: camps, unconferences, and trashing the talking head. Information Today, Medford NJ.

Bransford J., Brown A. L., Cocking R. R., Donovan M. S. & Pellegrino J. W. (2000) How people learn: Brain, mind, experience and school. Revised edition. National Academies Press, Washington.

Brennan K. (2013) Learning computing through creating and connecting. Computer 46(9): 52–59.

Brennan K. (2014) Audience in the service of learning: How kids negotiate attention in an online community of interactive media designers. Learning, Media and Technology: 1–20.

Brennan K. & Resnick M. (2013) Imagining, creating, playing, sharing, reflecting: How online community supports young people as designers of interactive media. In: Lavigne N. & Mouza C. (eds.) Emerging technologies for the classroom: A learning sciences perspective. Springer, New York: 253–268.

Brown A. L. & Campione J. C. (1996) Psychological theory and the design of innovative learning environments: On procedures, principles and systems. In: Schauble L. & Glaser R. (eds.) Innovations in learning: New environments for education. Lawrence Erlbaum, Hillsdale NJ: 234–265.

Brown J. S., Collins A. & Duguid P. (1989) Situated cognition and the culture of learning. Educational Researcher 18(1): 32–42.

Bruckman A. (1998) Community support for constructionist learning. Computer Supported Cooperative Work 7(1–2): 47–86.

Bruckman A. (2006) Learning in online communities. In: Sawyer K. (ed.) Cambridge handbook of the learning sciences. Cambridge University Press, New York: 461–472.

Brunvand S., Fishman B. & Marx R. (2005) Moving professional development online: Meeting the needs and expectations of all teachers. In: Dangel J. R. & Guyton E. (eds.) Research on alternative and non-traditional education. Association of Teacher Educators, Oxford: 205–232.

Buckingham D. (2007) Beyond technology: Children's learning in the age of digital culture. Polity, Malden MA.

Buckingham D. & Willett R. (eds.) (2006) Digital generations: Children, young people, and new media. Routledge, London.

Butler D. (2004) Self-determined teacher learning in a digital context: Fundamental change in thinking and practice. Unpublished doctoral dissertation. Dublin City University, Dublin.

Cherubini M., Gash H. & McCloughlin T. (2008) The DigitalSeed: An interactive toy for investigating plants. Journal of Biological Education 42(3): 123–129.

Cole M. & Wertsch J. V. (1996) Beyond the individual-social antinomy in discussions of Piaget and Vygotsky. Human-Development 39(5): 250–256.

Collins A. (2006) Cognitive apprenticeship. In: Sawyer K. (ed.) Cambridge handbook of the learning sciences. Cambridge University Press, Cambridge: 47–60.

Collins A. & Halverson R. (2009) Rethinking education in the age of technology: The digital revolution and schooling in America. Teachers College Press, New York.

Conneely C., Girvan C., Lawlor J. & Tangney B. (2015) An exploratory case study into the adaption of the Bridge21 model for 21st century learning in Irish classrooms. In: Butler D., Marshall K. & Leahy M. (eds.) Shaping our future: How the lessons of the past can shape educational transformation. Liffey Press, Dublin: 348–381.

Cuban L. (2001) Oversold and underused: Computers in the classroom. Harvard University Press, Cambridge MA.

Daly C., Pachler N. & Pelletier C. (2009) Continuing professional development in ICT for teachers: A literature review. BECTA, London.

de Jong T. & Pieters J. (2006) The design of powerful learning environments. In: Alexander P. A. & Winne P. H. (eds.) Handbook of educational psychology. Second edition. Routledge, Mahwah NJ: 739–754.

Doig B. & Groves S. (2011) Japanese lesson study: Teacher professional development through communities of inquiry. Mathematics Teacher Education & Development 13(1): 77–93.

Dweck C. (2000) Self-theories: Their role in motivation, personality, and development. Psychology Press, Lillington NC.

Farooq U., Schank P., Harris A., Fusco J. & Schlager M. (2007) Sustaining a community computing infrastructure for online teacher professional development: A case study of designing Tapped In. Computer Supported Cooperative Work 16(4–5): 397–429.

Fernandez M. L. (2010) Investigating how and what prospective teachers learn through microteaching lesson study. Teaching and Teacher Education 26(2): 351–362.

Fischer G. (2002) Beyond "couch potatoes": From consumers to designers and active contributors. First Monday 7(12). Available at http://firstmonday.org/article/view/1010/931

Fischer G. & Nakakoji K. (1997) Computational environments supporting creativity in the context of lifelong learning and design. Journal of Knowledge-Based Systems 10(4): 21–28.

Fishman B. J. & Davis E. A. (2006) Teacher learning research and the learning sciences. In: Sawyer K. (ed.) Cambridge handbook of the learning sciences. Cambridge University Press, Cambridge: 535–550.

Fishman B. J., Davis E. A. & Chan C. K. K. (2014) A learning sciences perspective on teacher learning research. In: Sawyer R. K. (ed.) Cambridge handbook of the learning sciences. Second edition. Cambridge University Press, New York: 707–725.

Flavell J. H. (1979) Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. American Psychologist 34(10): 906–911.

Fulton F., Doerr H. & Britton T. (2010) STEM teachers in professional learning communities: A knowledge synthesis. National Commission on Teaching and America's Future.

Gardner H. (1983) Frames of mind: The theory of multiple intelligences. Basic Books, New York.

Gardner H. (1991) The unschooled mind: How children think and how schools should teach. Basic Books, New York.

Gardner H. (1999) Intelligence reframed: Multiple intelligences for the 21st century. Basic Books, New York.

Gash H. (2014) Constructing constructivism. Constructivist Foundations 9(3): 302–310. Available at http://www.univie.ac.at/constructivism/journal/9/3/302.gash

Gash H. & McCloughlin T. (2010) Primary and secondary school differences in thinking about science. International Journal of Educational Researchers 1(3): 92–102. Available at http://ijer.eab.org.tr/pages/past-issue/2010-volume-1-issue-3.php

Gilligan C. (1982) In a different voice: Psychological theory and women's development. Harvard University Press, Cambridge MA.

Groupe Interuniversitaire Projet Sophia (2009) Formation des enseignants : un exemple de recherche-action: Chypre, France, lrlande, République tchèque, Slovénie. Review Internationale D'Éducation de Sèvres 51: 47–58. Available at https://ries.revues.org/660

Guskey T. R. (2002) Does it make a difference? Evaluating professional development. Educational Leadership 59(6): 45–51. Available at http://www.ascd.org/publications/educational-leadership/mar02/vol59/num06/Does-It-Make-a-Difference¢-Evaluating-Professional-Development.aspx

Harel I. & Papert S. (1990) Software design as a learning environment. Interactive Learning Environments 1(1): 1–32.

Hill H. C. (2007) Teachers' ongoing learning: Evidence from research and practice. The Future of Children 17: 111–128.

Hill H. C., Beisiegel M. & Jacob R. (2013) Professional development research: Consensus, crossroads, and challenges. Educational Researcher 42(9): 476–487.

Hoyles C., Noss R., Kent P. & Bakker A. (2010) Improving mathematics at work: The need for technomathematical literacies. Routledge, London.

Ito M. (2009) Engineering play: A cultural history of children's software. MIT Press, Cambridge MA.

Ito M., Baumer S., Bittanti M., boyd d., Cody R., Herr-Stephenson B., Horst H. A., Lange P. G., Mahendran D., Martínez K. Z., Pascoe C. J., Perkel D., Robinson L., Sims C. & Tripp L. (2009) Hanging out, messing around, geeking out: Living and learning with new media. MIT Press: Cambridge MA.

Jenkins H., Purushotma R., Weigel M., Clinton K. & Robison A. (2006) Confronting the challenges of participatory culture: Media education for the 21st century. MIT Press, Cambridge MA.

Kafai Y. B. (1995) Minds in play: Computer game design as a context for children's learning. Lawrence Erlbaum, Hillsdale NJ.

Kafai Y. B. & Resnick M. (eds.) (1996) Constructionism in practice: Designing, thinking, and learning in a digital world. Lawrence Erlbaum, Hillsdale NJ.

Kimmons R. (2015) Examining TPACK's theoretical future. Journal of Technology and Teacher Education 23(1): 53–77.

Knowles J. G. (1992) Models for understanding pre-service teachers and beginning teachers' biographies. In: Goodson I. F. (ed.) Studying teachers' lives. Routledge, London: 99–152.

Kolodner J., Camp P. J., Crismond D., Fasse B., Gray J., Holbrook J., Puntambekar S. & Ryan M. (2003) Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design into practice. Journal of the Learning Sciences 12(4): 495–547.

Koschmann T., Kelson A., Feltovich P. & Barrows H. (1996) Computer-supported problem-based learning: A principled approach to the use of computers in collaborative learning. In: Koschmann T. (ed.) CSCL: Theory and practice of an emerging paradigm. Lawrence Erlbaum, Hillsdale NJ: 83–124.

Krajcik J. S. & Blumenfeld P. C. (2006) Project-based learning. In: Sawyer K. (ed.) Cambridge handbook of the learning sciences. Cambridge University Press, Cambridge: 317–334.

Lajoie S. P. & Azevedo R. (2006) Teaching and learning in technology-rich environments. In: Alexander P. A. & Winne P. H. (eds.) Handbook of educational psychology Second edition. Routledge, Mahwah NJ: 803–821.

Lave J. & Wenger E. (1991) Situated learning: Legitimate peripheral participation. Cambridge University Press, New York.

Lieberman A. & Pointer Mace D. H. (2008) Teacher learning: The key to educational reform. Journal of Teacher Education 59(3): 226–234.

Liff S. & Shepard A. (2004) An evolving gender digital divide? Oxford Internet Institute Internet Issue Brief 2: 1–10.

Lin H. T. & Fishman B. (2009) Scaffolding teacher adaptation by making design intent explicit. In: Dimitracopoulou A., O'Malley C., Suthers D. D. & Reiman P. (eds.) Proceedings of the 9th international conference on computer supported collaborative learning 2: 159–161.

Mishra P. & Koehler M. J. (2006) Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record 108(6): 1017–1054.

Palfrey J. & Gasser U. (2008) Born digital: Understanding the first generation of digital natives. Basic Books, New York.

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

Papert S. (1987) Information technology and education: Computer criticism vs. technocentric thinking. Educational Researcher 16(1): 22–30.

Piaget J. (2007) The child's conception of the world. Rowman & Littlefield, Maryland. Originally published in French as: Piaget J. (1929) Representation du monde chez l'enfant.

Prensky M. (2001) Digital natives, digital immigrants. On the Horizon 9(5): 1–6.

Razzouk R. & Shute V. (2012) What is design thinking and why is it important? Review of Educational Research 82(3): 330–349.

Resnick M., Maloney J., Monroy-Hernandez A., Rusk N., Eastmond E., Brennan K., Millner A., Rosenbaum E., Silver J., Silverman B. & Kafai Y. (2009) Scratch: Programming for all. Communications of the ACM 52(11): 60–67. Available at http://cacm.acm.org/magazines/2009/11/48421-scratch-programming-for-all/fulltext

Riegler A. (2005) Editorial: The constructivist challenge. Constructivist Foundations 1(1): 1–8. Available at http://www.univie.ac.at/constructivism/journal/1/1/001.riegler

Rogoff B. (1994) Developing understanding of the idea of communities of learners. Mind, Culture, and Activity 1(4): 209–229.

Sawyer K. (2006) Explaining creativity: The science of human innovation. Oxford University Press, Oxford.

Scardamalia M. & Bereiter C. (1991) Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. Journal of the Learning Sciences 1(1): 37–68.

Schön D. (1983) The reflective practitioner: How professionals think in action. Basic Books, New York.

Seiter E. (2008) Practicing at home: Computers, pianos, and cultural capital. In: McPherson T. (ed.) Digital youth, innovation, and the unexpected. MIT Press, Cambridge MA, 27–52.

Selwyn N. (2009) The digital native: Myth and reality. New Information Perspectives 61(4): 364–379.

Selwyn N. (2011) Education and technology: Key issues and debates. Continuum, New York.

Selwyn N. (2014) Distrusting educational technology: Critical questions for changing times. Routledge, New York.

Sharkey M. (2014) Teachers' beliefs and constructivism. Unpublished masters' thesis. Dublin City University, Dublin.

Swanson K. N. & Leanness A. (2012) Edcamp: A qualitative exploration. Available at http://edcamp.org/wp-content/uploads/2012/07/Edcamp_Whitepaper_Final.pdf

Tapscott D. (2008) Grown up digital: How the net generation is changing your world. McGraw-Hill, New York.

Taylor P. C., Fraser B. J. & Fisher D. L. (1997) Monitoring constructivist classroom learning environments. International Journal of Educational Research 27: 293–302.

Turkle S. & Papert S. (1990) Epistemological pluralism: Styles and voices within the computer culture. Signs 16(1): 128–157.

Vygotsky L. S. (1978) Mind in society: Development of higher psychological processes 14th edition. Harvard University Press, Cambridge MA.

Wake G. (2014) Making sense of and with mathematics: The interface between academic mathematics and mathematics in practice. Educational Studies in Mathematics 86: 271–290.

Watanabe T. (2002) Learning from Japanese lesson study. Educational Leadership 59(6): 36–39.

Webster-Wright A. (2009) Reframing professional development through understanding authentic professional learning. Review of Educational Research 79(2): 702–739.

Wenger E. (1998) Communities of practice: Learning, meaning, and identity. Cambridge University Press, Cambridge.

Wenger E., McDermott R. & Snyder W. M. (2002) Cultivating communities of practice. Harvard Business School Press, Cambridge MA.

Westheimer J. (2008) Learning among colleagues: Teacher community and the shared enterprise of education. In: Cochran-Smith M., Feiman-Nemser S., McIntyre D. J. & Demers K. E. (eds.) Handbook of research on teacher education. Third edition. Routledge, New York: 756–783.

Windschitl M. (2002) Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. Review of Educational Research 72(2): 131–175.

Wiske M. S., Perkins D. N. & Spicer D. E. (2006) Piaget goes digital: Negotiating accommodation of practice to principles. In: Dede C. (ed.) Online professional development for teachers. Harvard Education Press, Cambridge MA: 9–67.