

Designing Online Experiences to Support Teacher Learning and Professional Development Across Subject Areas

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Abstract: Online professional development offers a scalable and often cost-effective method to support teacher learning. Yet, the relational, contextual, and situated nature of teacher learning raises important questions and design challenges for online environments that are often remote, decontextualized, and asynchronous. These challenges invite deeper explorations of how to leverage the affordances of online environments to design experiences that further support teacher learning. In this symposium we bring together a group of projects that engage teacher learning across subject areas and domains, and that represent a range of program formats—from MOOCs to instructional coaching models to professional learning communities. We will first discuss the rationale and outcomes of the specific design features built into each of the projects, and then draw implications for online teacher learning and professional development that cut across these projects.

Overview

The potential benefits of shifting teacher professional development (PD) to online and virtual environments seem self-evident. Such platforms are scalable and cost-efficient, able to reach teachers in remote locations, and to bypass logistical obstacles that have historically limited in-person opportunities (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009). At the same time, online environments pose unique design challenges for developers who wish to align experiences with principles of teacher learning. In this symposium, we discuss the design of online professional development experiences across program formats—from MOOCs to instructional coaching models to professional learning communities—and across subject areas. Each presentation aims to: a) Identify the specific teacher learning and professional development goals embedded in the online environment; b) Describe the online design features built specifically to accommodate teacher learning; c) Reveal how and in what ways the goals of the intervention have been met; and d) Discuss the broader implications for the design of online PD.

Professional development and teacher learning

The global shifts in K12 education toward interpretive and analytic skills and knowledge application (European Commission, 2015; NRC 2012), has created a steep learning curve for teachers. Improving access to high-quality professional development (PD) for teachers across subject areas has been identified as an immediate imperative (e.g., Wilson, 2013). Merritt (2016) noted that among the highest concerns articulated by teachers for improving practice is the need for more and flexible time to access and process new information. Likewise, Peltola et al. (2017) highlight a dearth of access to professional peers and geographic isolation for teachers.

Existing research on online PD suggests that it can support instructional change and teacher learning (e.g., O'Dwyer, Masters, Dash, de Kramer, Humez, & Russell, 2010). Thoughtful design iterations informed by research on best practices and principles of teacher learning are essential to the ongoing development of online PD.

Researchers of professional development have reached broad consensus about the features that characterize effective programs for teacher learning (Darling-Hammond, Hyler, & Gardner, 2017). Desimone (2009) identified five characteristics of professional development that support the development of teachers' knowledge, skills, and instructional practice: (a) duration; (b) content focus; (c) coherence with school, district, and state priorities and policies; (d) active learning; and (e) collective participation among teachers from the same school, grade, or department. These final two descriptive categories align with what we know about teacher learning, namely that teachers need opportunities to engage in problem-solving with their peers, to adapt and modify resources to their local contexts, to engage in collective, facilitated, analysis of classroom artifacts, and to receive ongoing content-specific instructional coaching (e.g., Penuel & Gallagher, 2009; Putnam & Borko, 2000). Not surprisingly, each of these activities underscores the deeply relational, contextual, and situated nature of teacher learning. For precisely these reasons, they raise important questions and design challenges for online environments that are often remote, decontextualized, and asynchronous.

Symposium organization

Across a range of program designs and subject matter contexts, the papers in this symposium address the central question of how to design online experiences that support teacher learning. Our goal is for audience members to walk away with concrete and empirically sound ideas for online PD design that are rooted in learning theory. Our session will follow the following structure:

1. Welcome and introduction by session chair (3 min)
2. Paper presentations (12 min each)
3. Discussant comments (12 min)
4. Full group discussion (15 min)

Designing online PD for science teachers through building social capital

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From 2010 to 2014, our team engaged in developing and delivering face-to-face PD using computer-supported complex systems curriculum and instruction. This work was built on known characteristics of high-quality PD for science teachers that included teacher's hands-on training for active sense-making, aligning with teaching contexts, exposure to scientific practices, and working with teachers as collaborators (e.g., Gerard et al., 2011). Findings from several studies (e.g., Yoon et al., 2017a) revealed high teacher satisfaction, high curricular utility, and increased student participation and learning outcomes. Importantly, we found that strategic efforts to build teacher's social capital (e.g., relationships for access to external resources) in addition to building teacher's human capital (e.g., individual knowledge and skills) improved their teaching from one year to the next (Yoon et al., 2018). This presentation will reveal an evaluation of our effort to design scaffolds and experiences for building teachers' social capital (SC) for online fully asynchronous environments that are not well structured to support such information exchange and relationship building (Booth, 2012).

We follow Coburn and Russell (2008) as modified in Yoon et al. (2017b) in terms of designing for specific categories of SC characteristics that can be applied to teacher PD experience: (1) *Tie quality*: How many people teachers talk to in relation to project implementation and the frequency of these interactions; (2) *Trust*: How willing teachers are to share information depends on their comfort in the community. In terms of capital and accessing resources, teachers may be motivated to share information about the project with the tacit expectation that they receive reciprocal information or resources; (3) *Depth of interaction*: The content of interactions that are more or less related to the project activities or goals. These interactions should be exchanges or reflections that lead to deeper conversations about and engagement with learning and instruction goals; and (4) *Access to expertise*: The competencies and resources available in teachers' network connections as well as teachers' knowledge of these competencies and resources and their ability to access them. Table 1 demonstrates a constellation of design choices we made in seeking to build teachers' SC online in light of what we know about high quality PD characteristics.

Table 1: Considerations for SC and high-quality PD activities that led to design choices

SC Category	High Quality PD Characteristics	Design Choice for Online Delivery
Tie Quality	Building relationships	<ul style="list-style-type: none"> Online profiles to share professional and personal information, e.g., <i>Write a post that describes your background (e.g., how long you have taught, unique skills or knowledge that might interest your classmates). After you have responded, use the forum to connect to other course participants by clicking "reply" to comment on their posts.</i>
	Peer-to-peer support	<ul style="list-style-type: none"> Seeding norms of support, e.g., <i>In the Discussion Forum, briefly discuss how one example impacted your thinking about systems. After you have responded, read a couple of other posts and click the heart icon for any that resonate with you.</i>
Trust	Orchestrating knowledge sharing	<ul style="list-style-type: none"> Online space to upload and download teacher-initiated resources; Facilitators actively connecting individuals with germane ideas to other individuals
	Teacher as knower and agent of change	<ul style="list-style-type: none"> Intentional design of the course with teacher leaders who participated in the previous face-to-face PD. Met monthly with three teachers who we called "Design Collaborators" (DCs) to critically think through aspects of PD and instruction.
Depth of Interactions	Active sense making and problem solving	<ul style="list-style-type: none"> Prompts that structure conversation around problems of practice, e.g., <i>Imagine your own classroom, what challenges do you see happening with your student population around building computational models? Think through some strategies with others.</i>
	Utility in real school contexts	<ul style="list-style-type: none"> Prompts that ask teachers to offer tried and true resources that they already use to teach scientific practices, e.g., scientific argumentation.
	Customization to teacher needs	<ul style="list-style-type: none"> Self-pacing in the online mode to accommodate teachers' learning trajectories with multiple forms of support to customize teacher needs, e.g., to take as long as they need to learn the StarLogo Nova programming language.
	Time to process new information	<ul style="list-style-type: none"> Prompts that ask teachers to reflect on previous practice, e.g., <i>Now that you have worked through Something's Fishy yourself, how is this different or similar to your approach to teaching about evolution? Write your thoughts in the discussion forum.</i>
Access to Expertise	Making practice public	<ul style="list-style-type: none"> In-class videos of DCs implementing the curriculum in their classrooms with prompts to focus course participants on strategies that can lead to successful implementation.
	Access to professional peers	<ul style="list-style-type: none"> DCs poised as experts who can problem solve with course participants. DCs instructed to monitor Discussion Forum conversations and chime in as needed. Help forum that is monitored by course facilitators including DCs who offer advice.

In the presentation, we discuss findings that illustrate both the positive and negative impacts of the social capital design. For example, all course participants found the video footage of expert teachers enacting the curriculum helpful, reflecting an affordance of the online mode that enabled the activity of making practice public (Lieberman & Mace, 2010). Moreover, all teachers noted and appreciated that these experts, who acted as facilitators in the course, offered quick responses in the help forum. This access to expertise shows the potential for online PD to address issues of access to professional peers and geographic isolation highlighted in recent PD policy documents (e.g., Peltola et al., 2017). However, in the category of trust, teachers had a harder time connecting with each other as individuals. We discuss implications that include the design of mechanisms to support forging connections with others who teach in similar contexts, a finding supported by Krasny et al. (2018) who highlight the benefit of learning in self-identified small groups in online courses.

Literacy coaching for dialogic text discussions: designing online experiences

Adaptive expertise (Hatano & Inagaki, 1986) is key to supporting teachers as they cultivate the skills to facilitate student-centered text discussions of high cognitive demand. In such dialogic text discussions students are provided opportunities to examine complex texts and engage in active meaning making with their peers to justify inferences based on text evidence (Alexander, 2006). These discussions are fundamentally different from traditional forms of discourse. They are, thus, relatively rare, partly because shifting from traditional forms of discourse towards dialogic discussions is challenging (Kucan, 2009).

In particular, teachers typically find it easier to enact open-ended questions at the beginning of a lesson as opposed to implementing new ways of responding productively to students' contributions (e.g., Franke et al., 2009). This skill of responding in-the-moment to advance student reasoning, without reducing the thinking demands, requires adaptive expertise, necessitating not only knowledge of potential 'talk moves' but also the ability to anticipate how particular talk moves are likely to alter the trajectory of student thinking.

In this presentation we discuss how a workshop based on situated learning theories built foundational knowledge (a common vision and vocabulary) that was used during coaching to further teachers' adaptive expertise. In order for shifts in discussion practice (from traditional towards dialogic) to occur, we suggest that teachers' existing mental models must be considered. While it would be common for teachers with traditional conceptions of instruction to "add-in" elements of teaching based on new conceptions of what is effective in classrooms, such shifts seldom lead to substantive or lasting change (Spillane, Reiser and Reimer, 2002). Instead, in order for sustained change to occur, teachers' existing mental models must be surfaced and considered in light of evidence of the effectiveness of teachers' current discussion patterns. Dissonance created between the use of certain talk moves and learning goals for student thinking and reasoning in text discussions is a potentially rich site for teacher learning, motivating teachers to co-construct how different talk moves could be more productive. In this way, teachers may be able to create new associations (Wilke & Losh, 2012) providing a foundation for when and why they should employ new facilitation moves during discussions, yielding adaptive expertise to facilitate dialogic discussions.

Video-based coaching provides conditions that can foster both dissonance and co-construction supporting conceptual change (Ibid.) That is, when coaches select short, two-minute video clips based on teacher-chosen goals, and provide teachers text to stimulate their reflection and meaning making of the exchanges in the text discussion (Borko, et al., 2008) they can promote teachers' own understanding of the association between particular talk moves and student thinking. We ground our discussion of the affordances of online coaching in theories of learning, but we also note several challenges posed by our recent work in online contexts – specifically, high attrition. Attrition from online learning experiences is not unusual, with dropout rates often ranging from 30%–50% (Stanford-Bowers, 2008). Exit interviews suggested that the additional time outside of the school day was a barrier for most participants who did not complete the experience.

Designing a virtual instructional coaching model for history teachers: analytic prompts to support asynchronous video analysis

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The recent proliferation of online platforms to support asynchronous video analysis (e.g., Edthena, Torsh, ClassForward) begs the question of how such platforms might be used in the context of online professional development. Drawing data from a 3-year design-based study on the development of an instructional coaching model for history teachers, we examine how coaches' use of analytic prompts supported productive asynchronous coach-teacher interaction and video analysis.

Research on effective professional development underscores the value of ongoing subject-specific instructional coaching (Darling-Hammond, Hyler, & Gardner, 2017). Yet, few school districts devote resources to supporting social studies teachers. The current project grew out of an effort to design a sustainable model of coaching that (1) leveraged the instructional expertise of local teacher leaders and (2) overcame the logistical hurdles that limit the scalability of face-to-face coaching models by shifting coaches' classroom observation and feedback to an online video platform. The focus of this presentation is on the design of video analysis prompts that support novice coaches in providing targeted and substantive instructional feedback.

An impressive body of research has explored the instructional potential of video for both preservice and inservice teachers (for a review, see Guadin & Chalias, 2015). Researchers have found that video analysis can support teachers in becoming more reflective, and more attentive to student thinking (e.g., Rosaen, Lundeborg, Cooper, Fritzen, & Terpstra, 2008). A handful of studies have traced the effects of video-based professional development experiences on teacher instructional practice (Sherin & van Es, 2009) and on student

learning (Allen, Pianta, Gregory, Mikami, & Lun, 2011; Roth et al., 2011). Two important findings emerge from this research. First, opportunities to engage in collective sense-making are critical in shifting teachers' perception of video (e.g., Borko, Jacobs, Eiteljorg, & Pittman, 2008; Visnovska & Cobb, 2013). At the same time, novices must be guided to notice those features most salient to effective instruction (van Es, Tunney, Goldsmith, & Seago, 2014). Importantly, all of this research was conducted in face-to-face contexts, in extended professional development or teacher education settings. A handful of coaching models (e.g., Allen et al, 2011) have incorporated asynchronous video analysis in their models, and these models rely on expert coaches who select short segments for teacher analysis.

Our presentation focuses on the templates for analytic prompts that we introduced in Year 2 of the study after noting that coaches and teachers rarely interacted in the online comments, and teachers often did not read coaches' comments. The templates included an observation or suggestion and a task. For example: *This discussion remained focused on the reliability of the documents, but we also want to help students draw inferences about the broader context. Can you identify and tag 3 moments when you could have pushed students to consider the broader historical context of the Cold War? What might you have said?* In comparing online comments before and after the introduction of the prompts, we found marked differences along temporal dimensions (e.g., shorter time lapse between posts, shorter completion of comment cycle) and substantive dimensions (e.g., coach and teacher comments focused on 1 or 2 components of instruction rather than multiple disconnected points). Interview data with coaches also suggested a greater sense of self-efficacy could have been related to their comfort using the platform effectively.

Two design principles emerge from this work that have implications for online professional development. First, online video analysis designs need to embed supports that focus teachers' attention. Second, online professional development designs should consider the needs of the teacher educators who mediate teachers' learning.

Examining the potential of an online professional learning community to support teachers' learning to enact dialogic practices in mathematics

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Research suggests that pull-out professional development has limited impact on teaching practice and student achievement (Gerstein et al., 2014; Jacob et al., 2017). Professional development is more effective when it is provided in combination with instructional coaching (Campbell & Malkus, 2011; Gibbons et al., 2017) and opportunities for teachers to do sustained work with colleagues (Coburn & Russell, 2008; Kennedy, 2016). This study examines elementary teachers' learning from an online, video-feedback community to understand the possibility of such an environment to extend the reach of face-to-face professional development.

There is increasing evidence that in order to achieve deep and lasting learning, students must have opportunities to make sense of mathematics concepts and procedures and generate and wrestle with ideas (Hiebert & Grouws, 2007; NRC, 2001). Teaching practices that support such opportunities are often referred to as *dialogic (or responsive)*, because discourse, deliberation, and social construction of ideas are central (Munter, Stein & Smith, 2015). Learning to facilitate classroom discussions and share intellectual authority with students is complex, takes time and support, and requires sustained practice. Teaching occurs largely in isolation, which limits opportunities for teachers to interact with colleagues, receive formative feedback, or consider alternate images of teaching (Lortie, 1975).

The online community was comprised of early-career elementary teachers who had been introduced to the dialogic routine called Number Talk through face-to-face PD or teacher education. Teachers were placed in inquiry groups, by grade bands with variation in school type and location. Interactions took place through an online platform designed to support asynchronous feedback on video. Following a structured schedule, teachers uploaded videos of their Number Talks (10-15 min), posed reflective questions, and gave and received feedback to/from others.

We analyzed the interactions among teachers in each inquiry group in relation to subsequent changes in their use of dialogic practices, using frameworks for dialogic teaching (Munter et al., 2015), pedagogical reasoning (Kavanagh, Conrad, & Dagogo-Jack, 2020), and video-based feedback (Borko et al., 2008). Findings suggest several ways that participation in the inquiry group led to different types of learning: Receiving feedback from others led teachers to take up new practices; commenting on others' videos helped novices reason about practices before trying them out; giving feedback to others provided opportunities to engage in pedagogical reasoning and solidify their own expertise. These developments became evident when examining the online interactions in relation to subsequent videos over several cycles of inquiry.

We hypothesize that repeated cycles of practice, posting videos, and giving and receiving feedback provided novice and experienced teachers opportunities to translate pedagogical approaches introduced in face-to-face professional development to their own classroom practice. Online formats can provide opportunities for repeated, supported practice of a pedagogically complex routine. The video-based feedback environment allows teachers to: observe other teachers and make their own practice public; slow down instructional practice to allow for pedagogical reasoning; receive constructive feedback from others to make incremental refinements; develop expertise by giving feedback to others on components of complex practices; and foster cross-school professional learning communities.

Designing professional development for open online learning: lessons from four change leadership MOOCs

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Massive open online courses (MOOCs) offer new opportunities to serve a global population of educators looking for online professional learning (Seaton, Coleman, Daries, Chuang, 2014). To explore MOOC-based professional learning, we developed a series of four courses on change leadership topics for teachers and administrators: Launching Innovation in Schools, Design Thinking for Leading and Learning, Envisioning the Graduate of the Future, and Competency-Based Education.

We developed our courses using a Blended Professional Community of Inquiry model, an adaptation of prior work from Garrison, Anderson, and Archer (2010) and Vaughn (2010). The community of inquiry model holds that effective learning designs attend to cognitive presence, teaching presence, and social presence. We argue that blended professional learning needs to strongly attend to *local presence*, how cohorts of learners interact in local study groups, and how learners take new insights, apply them in their local contexts, and bring artifacts of those efforts back into the course for discussion and feedback.

We have run each of these courses twice, while collecting data about participant experience and follow up activity through log data, surveys, assignments, forums, and post-course interviews. From these cycles of design research, we have identified three pairs of design elements that are central to learning in our courses.

Learning Circles and Facilitator's Guide. A Learning Circle is a facilitated group of learners who meet in person during an online course and ground course content in their specific context. Our implementation of Learning Circles was based on work by Peer2Peer University (P2PU) to support librarians in facilitating MOOC-based learning for patrons. The Facilitator's Guide was designed so that participants with minimal domain knowledge in change leadership would feel comfortable organizing a regular discussion/action group with peers. The guide includes sample meeting agendas for each unit of the course, discussion questions, and suggestions for making activities and assignments more collaborative.

Action-Oriented Assignments and Voices in Practice Case Studies. Course assignments support learners in community engagement; they ask participants to conduct exploration, reflection, planning, and evaluation. Learners submit artifacts from their interventions to course discussion forums for feedback and discussion. To help participants see what change leadership looks like in authentic school settings, each course includes a series of "Voices in Practice" mini-documentaries that showcase change leadership practices as they evolve across different communities. For instance, in Envisioning the Graduate of the Future, we documented practice in three schools: one starting a graduate profile development process, one in the thick of community-based profile development, and one with a completed graduate profile focused on revising program and curriculum.

Theory-Linked Activities and Take-Out Packages. Whenever possible, instruction about leadership theory is paired with specific activities that leaders can use. When we discuss the importance of reflecting on collaborative conversation, we engage participants in an activity called the Left-Hand Column Case, which is a specific protocol for debugging tough conversations. Most of these activities were developed for in-person workshops, and then adapted for the online context of MOOCs. To help participants go from engaging in online activities to leading those practices in-person, we provide Take-Out Packages, instructions for facilitating and debriefing activities from our online course in face-to-face contexts.

In our presentation, we will illustrate these strategies and discuss our approach to data collection and analysis to validate and refine these design hypotheses.

References

Alexander, R. (2006). *Towards dialogic thinking: Rethinking classroom talk*. York: Dialogos.

- Allen, J. P., Pianta, R. C., Gregory, A., Mikami, A. Y., & Lun, J. (2011). An interaction-based approach to enhancing secondary school instruction and student achievement. *Science*, 333, 1034–1037.
- Booth, S. E. (2012). Cultivating knowledge sharing and trust in online communities for educators. *Journal of Educational Computing Research*, 47(1), 1-31.
- Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M.E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.
- Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Educational Evaluation and Policy Analysis*, 30(3), 203–235.
- Campbell, P. F., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal*, 111, 430-454.
- Darling-Hammond, L., Hyler, M. E., Gardner, M. (2017). *Effective Teacher Professional Development*. Palo Alto, CA: Learning Policy Institute.
- Dede, C., Ketelhut, D.J., Whitehouse, P., Breit, L. & McCloskey, E.M (2009). Research Agenda for Online Teacher Professional Development. *Journal of Teacher Education*, 60(1), 8–19.
- Desimone, L. (2009). Improving impact studies of teachers' professional development: Towards better conceptualizations and measures. *Educational Researcher*, 38, 181–199.
- Ehsanipour, T. & Gomez Zaccarelli, F. (2017). *Exploring Coaching for Powerful Technology Use in Education* Stanford, CA: Center to Support Excellence in Teaching. Retrieved from <https://digitalpromise.org/wp-content/uploads/2017/07/Dynamic-Learning-Project-Paper-Final.pdf>
- European Commission (2015). *Science education for responsible citizenship*. European Union: Directorate-General for Research and Innovation Science with and for Society.
- Franke, M. L., Webb, N. M., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, 60(4), 380-392.
- Garrison, D. R., Anderson, T., & Archer, W. (2010). The first decade of the community of inquiry framework: A retrospective. *The Internet and Higher Education*, 13(1-2), 5-9.
- Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational Research Review*, 16, 41-67.
- Gerstein, R., Taylor, M. J., Keys, T. D., Rolfhus, E., & Newman-Gonchar, R. (2014). Summary of Research on the Effectiveness of Math Professional Development Approaches. REL 2014-010. *Regional Educational Laboratory Southeast*.
- Gerard, L. F., Varma, K., Corliss, S. B., & Linn, M. (2011). Professional development for technology-enhanced inquiry science. *Review of Educational Research*, 81, 408–448.
- Gibbons, L. K., Kazemi, E., & Lewis, R. M. (2017). Developing collective capacity to improve mathematics instruction: Coaching as a lever for school-wide improvement. *The Journal of Mathematical Behavior*, 46, 231-250.
- Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.), *Children development and education in Japan* (pp. 262-272). New York: Freeman.
- Hiebert, J. C., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 1, pp. 371–404). New York, NY: Information Age.
- Jacob, R., Hill, H., & Corey, D. (2017). The impact of a professional development program on teachers' mathematical knowledge for teaching, instruction, and student achievement. *Journal of Research on Educational Effectiveness*, 10(2), 379-407.
- Kavanagh, S. S., Conrad, J., & Dagogo-Jack, S. (2020). From rote to reasoned: Examining the role of pedagogical reasoning in practice-based teacher education. *Teaching and Teacher Education*, 89, 102991.
- Kennedy, M. M. (2016). How does professional development improve teaching? *Review of Educational Research*, 86, 945-980.
- Kleinknecht, M., & Gröschner, A. (2016). Fostering preservice teachers' noticing with structured video feedback: Results of an online- and video-based intervention study. *Teaching and Teacher Education*, 59, 45-56.
- Krasny, M.E., DuBois, B., Adameit, M., Atiogbe, R., Alfakihuddin, M.L.B., Bold-erdene, T., ... Yao, Y. (2018). Small groups in a social learning MOOC (slMOOC): Strategies for fostering learning and knowledge creation. *Online Learning*, 22(2), 119-139.
- Kucan, L. (2009). Engaging teachers in investigating their teaching as a linguistic enterprise: The case of comprehension instruction in the context of discussion. *Reading Psychology*, 30(1), 51-87.

- Lieberman, A., & Mace, D. P. (2010). Making practice public: Teacher learning in the 21st Century. *Journal of Teacher Education*, 61(1-2), 77-88.
- Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.
- McDonald, M., Kazemi, E., & Kavanagh, S. S. (2013). Core Practices and Pedagogies of Teacher Education: A Call for a Common Language and Collective Activity. *Journal of Teacher Education*, 64(5), 378-386.
- Merritt, E. G. (2016). Time for teacher learning, planning critical for school reform: Students aren't the only ones who need more time to learn; teachers also need more and better time for learning and for planning. *Phi Delta Kappan*, 98(4), 31.
- Munter, C., Stein, M.K. and Smith, M.S. (2015). Dialogic and direct instruction: Two distinct models of mathematics instruction and the debate(s) surrounding them. *Teachers College Record*, 117 (11), 1-32.
- National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. Washington, DC: The National Academies Press.
- O'Dwyer, L. M., Masters, J., Dash, S., Magidin deKramer, R., Humez, A., & Russell, M. (2010). *e-Learning for educators: Effects of on-line professional development on teachers and their students: Findings from four randomized trials*. Retrieved from http://www.bc.edu/research/intasc/PDF/EFE_Findings2010_Report.pdf
- Peltola, P., Haynes, E., Clymer, L., McMillan, A., & Williams, H. (2017). *Opportunities for teacher professional development in Oklahoma rural and nonrural schools* (REL 2017-273). Washington, DC: U.S.
- Penuel, W.R. & Gallagher, L.P. (2009). Preparing teachers to design instruction for deep understanding in middle school earth science, *Journal of the Learning Sciences*, 18(4), 461-508.
- Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4-15.
- Rosaen, C.L., Lundeberg, M., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing noticing: How does investigation of video records of practice change how teachers reflect on their experience? *Journal of Teacher Education*, 59(4), 347-360.
- Roth, K.J., Garnier, H.E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N.I. (2011). Video-based lesson analysis: Effective science PD for teacher and student learning. *Journal of Research in Science Teaching*, 48(2), 117-148.
- Seaton, D., Coleman, C., Daries, J., & Chuang, I. (2014). Teacher Enrollment in MITx MOOCs: Are We Educating Educators?. Available at SSRN 2515385.
- Sherin, M.G. & van Es, E.A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education*, 60(1), 20-37.
- Spillane, J. P., Reiser, B. J., & Reimer, T. (2002). Policy implementation and cognition: Reframing and refocusing implementation research. *Review of educational research*, 72(3), 387-431.
- van Es, E.A., Tunney, J., Goldsmith, L.T., & Seago, N. (2014). A framework for the facilitation of teachers' analysis of video. *Journal of Teacher Education*, 65(4), 340-356.
- Vaughan, N. D. (2010). A blended community of inquiry approach: Linking student engagement and course redesign. *The Internet and Higher Education*, 13(1-2), 60-65.
- Visnovska, J., & Cobb, P. (2013). Classroom video in teacher professional development program: community documentational genesis perspective. *ZDM Mathematics Education*, 45, 1017-1029.
- Wilke, R. A., & Losh, S. C. (2012). Exploring mental models of learning and instruction in teacher education. *Action in Teacher Education*, 34(3), 221-238.
- Wilson, S. M. (2013). Professional development for science teachers. *Science*, 340, 310-313.
- Yoon, S. (2018). Mechanisms that couple intentional network rewiring and teacher learning to develop teachers' social capital for implementing computer-supported complex systems curricula. In S. Yoon and K. Baker-Doyle. *Networked by design: Interventions for teachers to develop social capital*. Routledge Press.
- Yoon, S., Anderson, E., Koehler-Yom, Evans, C., Park, M., J., Sheldon, J., Schoenfeld, I., Wendel, D., Scheintaub, H., & Klopfer, E. (2017a). Teaching about complex systems is no simple matter: Building effective professional development for computer-supported complex systems instruction. *Instructional Science*, 45(1), 99-121.
- Yoon, S., Koehler-Yom, J., & Yang, Z. (2017b). The effects of teachers' social and human capital on urban science reform initiatives: Considerations for professional development. *Teachers College Record*, 119(4), 1-32.