SUPPORTING COMMUNITIES OF INQUIRY IN ASYNCHRONOUS, ONLINE MATHEMATICS PROFESSIONAL DEVELOPMENT

Angela Knotts
WestEd
aknotts@wested.org

Nanette Seago
WestEd
nseago@wested.org

Jill Neumayer DePiper
WestEd
jdepipe@wested.org

Asynchronous, online mathematics teacher professional development (PD) was designed to align with research on teacher professional learning as well as to support Communities of Inquiry (e.g., Garrison et al., 2000). The intervention included two actively facilitated formats and a structured independent condition, where facilitation was integrated into the design of the intervention. Participants' responses to intervention activities were analyzed using indicators of Garrison et al.'s Community of Inquiry framework, seeking to understand the ways in which the intervention enabled participant learning across facilitation formats. Analysis has implications for building the CoI framework into subsequent online asynchronous mathematics teacher PD as a way to increase teacher learning, build community, and effectively scale interventions.

Keywords: Professional Development, Teacher Knowledge, Online and Distance Education, Technology

Significance and Purpose

High-quality professional learning is widely accepted as a core component of effective teaching and learning and meaningful school reform (Borko et al., 2014; DeMonte 2013; Heller et al. 2012; Polly et al. 2015; Yoon et al. 2007). Online teacher professional development (PD) opportunities are poised to play a key role in bringing meaningful, effective professional learning to teachers on a broad scale (Killion, 2013), with experts in the field as well as policy makers advocating for more teacher PD to be delivered online (Dede et al., 2009, 2016; US Department of Education, 2010). While the range of potential designs for online PD is vast, offerings can generally be categorized as synchronous (all participants interacting in real time) asynchronous (participants work with materials at their own pace for submission and later feedback), or hybrid (involving both synchronous and asynchronous components) (Fishman, 2016).

A general consensus has emerged within the field regarding the design features of PD most likely to impact teacher and student outcomes, both in general and in mathematics specifically, such as sustained duration, content area-specificity, coherence, active/practice-based learning, collaboration, access to models of effective practice, and expert facilitation/coaching (Elmore, 2002; Garet et al., 2001; Loucks-Horsley et al., 2010; Darling-Hammond et al., 2017); how to integrate these elements in an online setting is less clear. Teachers report that the ability to access online PD anytime is very or extremely important (Parsons et al., 2019), and asynchronous forms of online PD have resulted in positive findings related to teachers' attitude and self-efficacy (An, 2018) as well as high satisfaction and relatively high levels of information sharing (Yoon et al., 2020).

This paper focuses on the ways that careful design choices support the development of a community of inquiry in an online, asynchronous video-based PD—*Video in the Middle: Flexible Digital Experiences for Mathematics Teacher Education* (VIM). A major goal of the VIM project was to demonstrate that online, asynchronous video-based teacher PD can be designed and implemented that both embodies the features recognized by the field as

characterizing effective, high-quality professional learning and also democratizes such PD by increasing teacher access to engaging, meaningful practice-based professional learning.

Theoretical Framework

To integrate attention to key learnings about mathematics teacher PD with research on asynchronous online learning, the VIM project design and development is theoretically grounded in key literature on Communities of Inquiry (CoI; Garrison et al., 2001). The CoI framework emphasizes three crucial elements of a successful educational experience: cognitive presence, social presence, and teaching presence. According to the CoI framework, worthwhile learning occurs through the interaction of these three core elements.

Cognitive presence is "the extent to which the participants in a community of inquiry are able to construct meaning through sustained communication" (Garrison et al., 2001, p. 89; Anderson et al., 2001; Garrison & Archer, 2000). Garrison has argued extensively that "asynchronous online learning can create a rich cognitive presence capable of supporting effective, higher-order learning" (2003, p. 47). He suggests that this is best accomplished through a cycle of practical inquiry where participants move through four phases: (1) a *triggering* event where a problem is identified for further inquiry; (2) *exploration*, where an individual explores the issue; (3) *integration*, where learners make meaning from ideas generated during the exploration phase; and (4) *resolution*, where participants apply new skills and knowledge.

Social presence is defined as the ability of participants to project their personal characteristics into the community, thereby presenting themselves to the other participants as 'real people,' facilitating both enjoyment of the experience as well as the process of critical thinking they undertake (Rourke et al., 1999; Anderson et al., 1999; Garrison et al., 2001). It supports cognitive presence (and therefore cognitive objectives) through its ability to instigate, sustain, and support critical thinking among a community, and also plays a role in participant retention by ensuring that participants find interactions enjoyable and fulfilling. Richardson and Swan (2003) found that social presence positively affects both student and instructor course satisfaction, and participants who perceived high social presence learned more than those who perceived low social presence (Richardson & Swan, 2003).

Teaching presence—the intentional design, facilitation, and direction of cognitive and social processes—has three components: (1) instructional design and organization; (2) facilitating discourse; and (3) direct instruction (Garrison et al., 2000; Anderson et al., 2001; Garrison & Arbaugh, 2007). It is theorized to support and enhance social and cognitive presence.

Video in the Middle (VIM) Project Design

Drawing on the existing face-to-face PD *Learning and Teaching Linear Functions: Videocases for Mathematics Professional Development* (Seago et al., 2004), the VIM project created 40 asynchronous online mathematics PD modules and researched their effectiveness. Each two-hour module is centered around a purposefully selected video clip from a real mathematics classroom and designed to facilitate teachers' noticing skills (van Es & Sherin, 2002) and mathematical knowledge for teaching linear functions (Ball & Bass, 2002). VIM modules are designed to be rich, research-based, open education resources that can be used in a wide variety of settings with less up-front time and resource investment than many other high-quality offerings. The modular nature of the design means that school/district PD providers can select particular modules or series of modules they feel meet the needs of their teachers, or they can choose pre-selected "pathways" of modules sequenced by the VIM research and design teams to address specific learning goals. Modules can be implemented in either a facilitated

format where a PD leader responds to participants' contributions asynchronously, or in a structured independent format where participants engage in activities and respond to fellow participants' contributions without monitoring or active facilitation from a PD leader.

VIM Module Design

Each module includes the same series of common activities across three phases. In the pre-video phase, participants are introduced to the learning goals related to mathematical content knowledge and pedagogy (Seago et al., 2018). They then solve and reflect on a math task, post their work on a Community Wall, and comment on others' work. In facilitated formats, facilitators also respond to posts. Participants also consider a variety of solution strategies for the task and review a brief "Mathematician's Commentary" on the task. In the video phase, participants review the context of a video clip where students explore the task, watch the video, and analyze it through the lens of a set of framing questions. They also re-examine the solution methods in connection to the video clip and annotate an excerpt from the video transcript. They then re-watch the video with a different framing question, annotate moments in the video, and respond to annotations from fellow participants, expert math educators, and, in facilitated formats, facilitators. In the post-video phase, participants complete a reflection in response to a prompt related to the module learning goals, post their reflection on a Community Wall, and respond to others' posts. The module concludes with teachers engaging in a "Bridge to Practice" activity that asks them either to consider how they might incorporate new strategies and ideas into their own classroom practice or respond to an artifact of practice through the lens of what they have learned.

Pre-video Activities	Video in the Middle	Post-video Activities
0. Introduction to learning goals 1. Explore math task and reflect in journal 2. Share your work on the math task 3. Consider other solutions and perspectives	4. Review the context of the lesson 5. Watch video and reflect 6. Reflect on the lesson graph and solution methods 7. Annotate video transcript 8. Watch video with math educator commentary	9. Module reflection 10. Bridge to practice

Figure 1: Overview of VIM module common learning activities

Cognitive Prescence, Social Prescence, and Teaching Presence in VIM Module Design

VIM modules were designed to embody the three core elements of a community of inquiry as described by Garrison et al. (2000, 2001). Cognitive presence was built into each VIM module in the form of multiple practical inquiry cycles—for example, around the math task activity and the central video phase (table 1). Each module comprises a larger-scale practical inquiry cycle as well.

Table 1: Alignment of elements and categories of Community of Inquiry framework (Garrison et al., 2001) with VIM module activities

Categories	*Opportunities in VIM Modules*	
Triggering Event	Introduction to math task	Introduction to video (context and frame)
Exploration	Solving & reflecting on math task; sharing & comparing solution strategies	Exploring other ideas about video (math educator, facilitator, other participants)

Integration	Responding to/discussing solution strategies	Responding to/discussing video commentary
Resolution	Reconciling alternative solution methods & mathematician commentary with own ideas & method	Bridge to Practice activity

VIM modules promote social presence through Community Walls where participants post and respond to others' math task solutions and reflections as well as activities where they analyze, comment on, and respond to others' comments about the video and transcript. Prompts included:

- "After you have posted your work, take some time to look at the solutions of others. What do you notice? What do you wonder? Add comments to the posts of your peers and/or create a new post to add a general comment on the wall. Please check back later if you are the first to post."
- "As you watch, post comments at the points during the video that highlight how Debra probes Siri to explain further and how Debra's moves support Tiffany to make her explanation clearer for the class. Feel free to pause the video when reading comments and respond to them if you'd like."

In facilitated formats, facilitators also respond to posts.

The video task was also designed to foster social presence; Sherin (2004) points out that video is similar to authentic experience in that it positively affects motivation and interest. Multiple studies have found that there exists a higher level of satisfaction when teacher education courses use video rather than narrations of experience (Choi & Johnson, 2007; Moreno & Valdez, 2007).

Table 2: Alignment of social presence categories of Community of Inquiry framework (Garrison et al., 2001) with VIM module activities

Categories	*Opportunities in VIM Modules*	
Affective, Interactive, and Cohesive Responses	Math task Community Wall interactions	Video commentary interactions

Teaching presence was built into each VIM module with a team of veteran math educators, researchers, and educational technology designers who worked on the design and organization, without the assumption that a member of the design team would facilitate the module. Available pre-sequenced "pathways" of VIMs are another example of instructional design and organization. While in online, asynchronous settings, facilitation of discourse is often carried out by an instructor or facilitator commenting on responses, raising questions to move discussions in a particular direction, keep discourse moving efficiently, and balance participation, Garrison et al. (2000) note that facilitation is a responsibility that may be shared among some or all participants in the learning experience, particularly with adult populations. To facilitate discourse, the VIM modules, and particularly the framing and reflection questions that wrap around learning activities, guide and focus participants' interaction around the module artifacts and materials. Facilitator training materials further support PD leaders in responding to posts and

guiding discussion to achieve the module learning goals. In VIM modules, subject matter knowledge is injected strategically as direct instruction through pre-selected and sequenced artifacts such as the Solution Methods document, the Mathematician's Commentary on the task, pre-embedded expert commentary on the video and transcript, and professional readings used to frame Bridge to Practice activities. To increase interaction and help participants to recognize the developmental progression of the inquiry process (Garrison & Arbaugh, 2007), VIM modules include metacognitive journal and Community Wall activities that prompt participants to consider how the module activities influenced their understand and beliefs about mathematics teaching and learning (for example, "I used to think… Now I think…").

Table 3: Alignment of teaching presence categories of Community of Inquiry framework (Garrison et al., 2001) with VIM module activities

Categories	*Opportunities in VIM Modules*	
Instructional Design and Organization	Selection of module goals, task, & prompts; sequencing of task-related activities	Selection of module goals, video, & prompts; sequencing of video-related activities
Facilitating Discourse	Community Wall prompts and interactions	Video analysis prompts and interactions
Direct Instruction	Solution Methods pdf; Mathematician's Commentary slides	Math educator pre-entered prompts

Research Design

California middle and high school teachers were recruited to participate in a Spring 2020 pilot study to address the following research question: *Which elements of the CoI framework were evident in teacher and facilitator responses?* All teachers experienced the same sequence of four, two-hour modules for a total of eight hours of professional development over the course of twelve weeks (February through April 2020). Modules were offered in three formats: (1) project staff-facilitated (n = 17), (2) district leader-facilitated (n = 18), and (3) structured independent (n = 26). Teachers in each of the two district leader-facilitated cohorts were all from the same district, while the other two groups included teachers from various districts.

All three formats included a content focus, the same asynchronous opportunities for sharing solution methods and written reflections with colleagues, and attention to bringing what they learned into practice. Facilitated formats differed from the structured independent format in two ways: 1) pace (project-staff and district-facilitated formats asked teachers to complete one module every two weeks, while teachers in the independent format worked at their own pace, and 2) the role of the facilitator. As a clear and well-defined structure to each VIM module was established during the design phase reflecting research on teacher PD, attention to student thinking, and the importance of teacher reflection, the role of the facilitator in both the project staff- and district-facilitated formats focused on commenting on teachers' posts, encouraging teachers to complete modules, and responding to journal reflections. Project and district facilitators participated in a 90-minute video-conference orientation with project staff, including an overview of the study and timeline, VIM module structure, and online tools. Facilitators also had access to a web-based facilitator guide and video tutorial demonstrating how to use the online tools to respond to participants.

Participants

Participating teachers taught middle school math, Algebra 1, or a first-year high school math course such as Math 1 or Integrated 1.

Teachers in the district leader-facilitated condition were recruited by mathematics leaders from each of two school districts; each of the two leaders then served as the facilitator for their district group. Additional teachers were recruited from across California and randomized into either the structured independent condition or the project staff-facilitated condition. Where multiple teachers were recruited from the same district, teachers were randomly split between the two conditions. Where single teachers were recruited from a site, singleton teachers were matched by similar site location or demographics; matched pairs were then randomized into the two conditions. Of the 68 teachers who began the study, 82% completed all or nearly all study activities across the four modules.

Data Collection

In both facilitated and independent VIM cohorts, participants had eight opportunities (two opportunities per module) to engage with others' posts via Community Walls. Rourke et al. (2001) identify three categories of social presence indicators: **affective** responses (expressions of emotion, feelings, and mood), **interactive** responses (threaded interchanges of socially appreciative messages), and **cohesive** responses (serving to build and sustain a sense of group commitment). Posts and replies from all Community Walls in all cohorts were analyzed for evidence of social presence. Each post and reply showing evidence of social presence was categorized as an affective response, an interactive response, or a cohesive response. Posts and replies were categorized as *affective responses* if they included emoticons, exclamation points, or other text intended primarily to communicate mood or emotion (Kuehn, 1993; Gunawardena & Zittle, 1997). Replies were categorized as *interactive responses* if they expressed social appreciation for the original post or a previous reply. Posts and replies were categorized as *cohesive responses* if they included phatics (communication which serves to establish or maintain social relationships rather than to impart information), salutations, vocatives (addressing participants by name), or addressing the group as "we," "our," or "us." Percentages of posts showing evidence of each category of social presence were calculated for each of the three facilitation formats.

All participants also had four opportunities to engage with others' posts as well as pre-entered "Mathematics Educator" posts in the video analysis activity, an example of teaching presence through direct instruction. Responses to these posts were reviewed for evidence that they had impacted participants' thinking about the video clip or prompted them to engage in deeper reflection around moments or interactions referenced by the Mathematics Educator posts.

Findings and Discussion

Evidence of Social Presence in VIM Modules

Analysis of participants' Community Wall responses across both facilitated and independent cohorts revealed examples of affective, interactive, and cohesive responses. Analysis of Community Wall posts found that numerous posts in all three participation formats either contained or inspired replies/rejoinders that contained evidence of affect (14.8% locally facilitated, 37% project-facilitated, 10.5% structured independent):

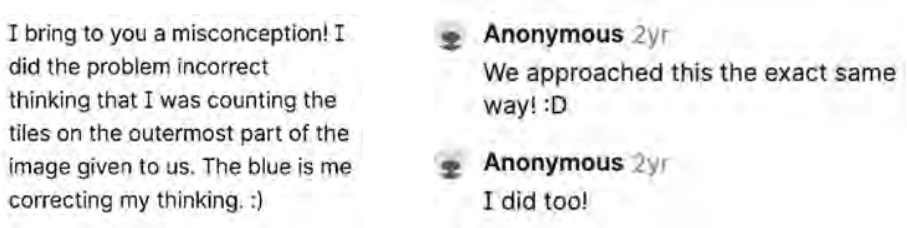

Figure 2: Affective responses in facilitated (left) and independent (right) VIM cohorts

Interactive responses were the most common type of response across all three cohorts (43.7% locally facilitated, 65.2% project-facilitated, 33.7% structured independent), with participants routinely commenting in socially appreciative ways on others' math work or reflections in response to what they found interesting or raised questions for them.

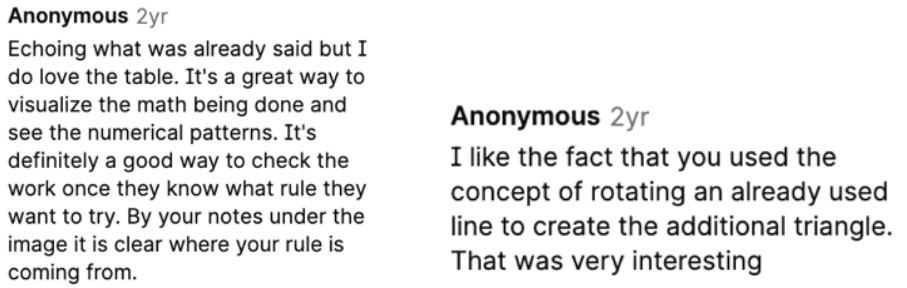

Figure 3: Interactive responses in facilitated (left) and independent (right) VIM cohorts

Cohesive responses were the least common type of response across all cohorts, with only a few examples in each (5.2% locally facilitated, 3.7% project-facilitated, 4.4% structured independent). We hypothesize that this was due in part to technological limitations that defaulted to anonymous posts and replies.

Figure 4: Phatics and vocatives as indicators of cohesive responses in facilitated (left) and independent (right) cohorts

Evidence of Teaching Presence in VIM Modules

Of the three core elements, it is perhaps teaching presence which is the least obvious in terms of how effectively it is accomplished in VIM modules given that they are designed to be used with or without active facilitation; even when used with a facilitator, interaction is significantly lighter touch as compared to the role a facilitator might play in other PD experiences. We have already seen the manner in which the intentional design and organization of VIM modules contributes to both cognitive and social presence through the selection of tasks and video, module goals, framing and reflection questions, and Community Wall prompts.

We can see evidence of the impact of direct instruction when participants are asked to comment on moments in the video and respond to other comments, including comments pre-inserted by the design team to draw teachers' attention to key moments in the video and encourage discussion around them (figure 5).

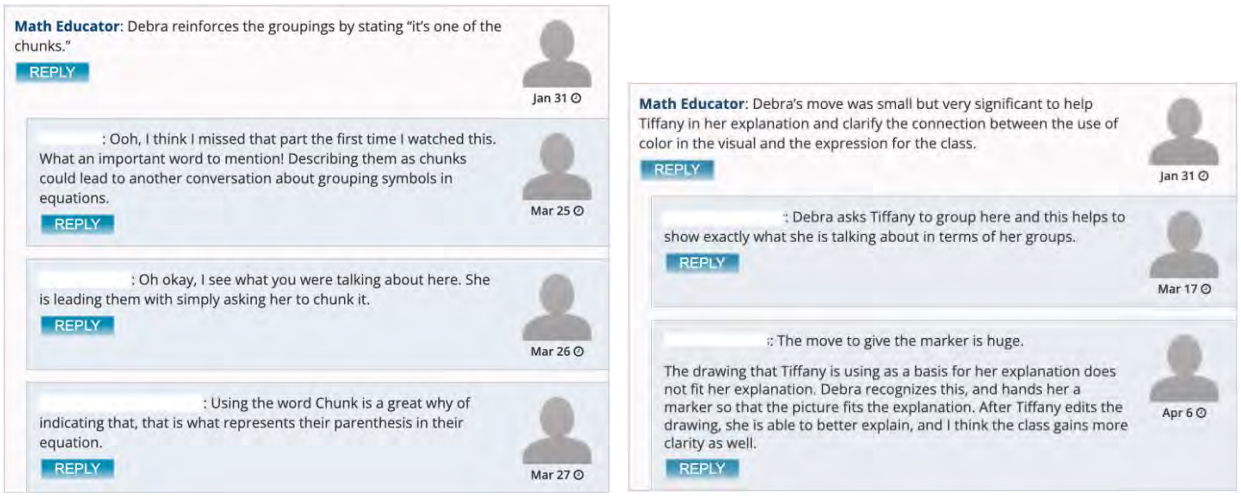

Figure 5: Positive participant responses to pre-inserted video comments from facilitated (left) and independent (right) cohorts

In facilitated cohorts, facilitation of discourse was moderately provided by human facilitators monitoring and responding to posts in order to guide discussion and probe participants' thinking. In both facilitated and structured independent cohorts, a level of in-the-moment facilitation was also provided by participants interacting with module elements/resources such as the mathematical task work, others' perspectives on the mathematics, and most critically, the central video clip. We hypothesize that the unique nature of authentic classroom video described by Sherin (2004) and the intrinsic motivation and interest it inspires for teachers in combination with the prompts, framing questions, and reflection questions fosters a level of discourse that may not otherwise be achieved in an asynchronous, online PD experience.

Conclusion

If schools and districts are to scale quality PD in a cost-effective and widely accessible manner, innovative tools and strategies that do not rely on individual providers spending extensive face-to-face time with small groups of teachers are needed (Cai et al., 2017). Highly structured online asynchronous PD opportunities—with or without active facilitation—may have a role to play in bringing effective, flexible professional learning to a significantly wider audience if they are designed in a way that reflects features of effective PD recognized by the field and supports the development of communities of inquiry. The VIM module design and pilot study provide promising evidence that this can be accomplished, while also pointing us to possible new directions for future development and research.

In particular, greater social presence may be accomplished through technology that avoids anonymous posts and allows for participant profile information and photos. Specific prompts could also be added to encourage participants to revisit previous Community Walls to review and engage with new posts. Additional opportunities for interaction with fellow participants could also be created, for example in relation to the "Bridge to Practice" activities.

Acknowledgments

This project is supported by the National Science Foundation (NSF), through NSF #1720507. Any opinions, findings, and conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the NSF.

References

An, Y. (2018). The effects of an online professional development course on teachers' perceptions, attitudes, self-efficacy, and behavioral intentions regarding digital game-based learning. *Educational Technology Research and Development, 66,* 1505–1527.

Anderson, T. D., Rourke, L., Garrison, D. R., & Archer, W. (1999). *Social presence in computer conferencing: Chewing the phat (ic)* [Unpublished manuscript].

Anderson, T., Rourke, L., Garrison, D. R., & Archer, W. (2001). Assessing teaching presence in a computer conference environment. *Journal of Asynchronous Learning Network,s 5*(2), 1-17.

Ball, D.L. & Bass, H. (2002). Toward a practice-based theory of mathematical knowledge for teaching. In B. Davis & E. Simmt (Eds.), *Proceedings of the 2001 Annual Meeting of the Canadian Mathematics Education Study Group* (pp. 3–14).

Borko, H., Koellner, K., & Jacobs, J. (2014). Examining novice teacher leaders' facilitation of mathematics professional development. *The Journal of Mathematical Behavior, 33*, 149–167.

Cai, J., Morris, A., Hwang, S., Hohensee, C., Robinson, V., & Hiebert, J. (2017). Improving the impact of educational research. *Journal for Research in Mathematics Education, 48*, 2–6.

Choi, H., & Jonson, S. (2007). The effect of problem-based video instruction on learner satisfaction, comprehension and retention in college courses. *British Journal of Educational Technology, 38*(5), 885e895.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development.* Learning Policy Institute. https://learningpolicyinstitute.org/sites/default/files/product-files/Effective_Teacher_Professional_Development_REPORT.pdf

Dede, C., Eisenkraft, A., Frumin, K., & Hartley, A. (2016). *Teacher learning in the digital age: Online professional development in STEM education.* Cambridge, MA: Harvard Education Press.

Dede, C., Ketelhut, D.J., Whitehouse, P., Breit, L., & McCloskey, E.M. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education, 60*(1), 8-19.

DeMonte, J. (2013). *High-quality professional development for teachers: Supporting teacher training to improve student learning.* Washington, DC: Center for American Progress.

Elmore, R. F. (2002). *Bridging the gap between standards and achievement: The imperative for professional development in education.* Washington, DC: Albert Shanker Institute.

Fishman, B. (2016). Possible futures for online teacher professional development. In C. Dede, A. Eisenkraft, K. Frumin, & A. Hartley (Eds.), *Teacher learning in the digital age: Online professional development in STEM Education.* Camrbidge, MA: Harvard Education Press.

Garrison, D. R. (2003). Cognitive presence for effective asynchronous online learning: The role of reflective inquiry, self-direction and metacognition. In J. Bourne & J. C. Moore (Eds.), *Elements of quality online education: Practice and direction* (pp. 47–58). Sloan-C.

Garrison, D.R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*(2), 87-105.

Garrison, D.R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education, 15*(1), 7-23.

Garrison, D.R., & Arbaugh, J.B. (2007). Researching the community of inquiry framework: Review, issues, and future directions. *The Internet and Higher Education, 10*(3), 157-172.

Garrison, D.R., & Archer, W. (2000). *A transactional perspective on teaching and learning: A framework for adult and higher education.* Oxford, UK: Pergamon.

Garet, M.S., Porter, A.C., Desimone, L., Birman, B.F., & Yoon, K.S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38*, 915–945.

Gunawardena, C.N., & Zittle, F.J. (1997). Social presence as a predictor of satisfaction within a computer-mediated conferencing environment. *The American Journal of Distance Education, 11*(3), 8-26.

Heller, J.I., Daehler, K.R., Wong, N., Shinohara, M., and Miratrix, L.W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching, 49*(3): 333–362.

Killion, J., & Learning Forward. (2013). *Meet the promise of content standards: Tapping technology to enhance*

professional learning. Learning Forward. https://learningforward.org/wp-content/uploads/2017/09/tapping-technology-to-enhance-professional-learning.pdf

Kuehn, S. (1993). Communication innovation on a BBS: A content analysis. *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century, 1*(2). http://jan.ucc.nau.edu/~ipctj/1993/n2/kuehn.text

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., & Hewson, P. (2010). *Designing professional development for teachers of science and mathematics (3rd Edition).* Thousand Oaks, CA: Corwin Press.

Moreno, R., & Valdez, A. (2007). Immediate and delayed effects of using a classroom case exemplar in teacher education: the role of presentation format. *Journal of Educational Psychology, 99*(1), 194-206.

Parsons, S. A., Hutchison, A. C., Hall, L. A., Parsons, A. W., Ives, S. T., & Leggett, A. B. (2019). U.S. teachers' perceptions of online professional development. *Teaching and Teacher Education, 82*, 33–42.

Polly, D., McGee, J., Wang, C., Martin, C., Lambert, R., and Pugalee, D. (2015). Linking professional development, teacher outcomes, and student achievement: The case of a learner-centered mathematics program for elementary school teachers. *International Journal of Educational Research, 72*, 26–37.

Richardson, J. C., & Swan, K. (2003). Examining social presence in online courses in relation to students' perceived learning and satisfaction. *Journal of Asynchronous Learning Networks, 7*(1), 68−88.

Rourke, L., Anderson, T. Garrison, D. R., & Archer, W. (2001). Assessing social presence in asynchronous, text-based computer conferencing. *Journal of Distance Education, 14*(3), 51-70.

Rourke, L., Anderson, T., Garrison, D. R., & Archer, W. (1999). Assessing social presence in asynchronous text-based computer conferencing. *Journal of Distance Education, 14*(2), 50-71.

Seago, N., Koellner, K. Jacobs, J. (2018). Video in the middle: Purposeful design of video-based mathematics professional development. *Contemporary Issues in Technology and Teacher Education, 18*(1).

Seago, N., Mumme, J., & Branca, N. (2004). *Learning and teaching linear functions.* Portsmouth, NH: Heinemann.

Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Using video in teacher education* (pp. 1-28). Oxford, UK: Elsevier.

U.S. Department of Education (2010). *Transforming American education: Learning powered by technology; National education technology plan.* Washington, DC: U.S. Department of Education, Office of Educational Technology.

van Es, E.A., & Sherin, M.G. (2002). Learning to notice: Scaffolding new teachers' interpretation of classroom interactions. *Journal of Technology and Teacher Education, 10,* 571-596.

Yoon, K.S., Duncan, T., Lee, S.W.-Y., Scarloss, B., and Shapley, K. (2007). *Reviewing the evidence on how teacher professional development affects student achievement (Issues and Answers Report, REL 2007-No. 033)*. National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Yoon, S.A., Miller, K., Richman, T., Wendel, D., Schoenfeld, I., Anderson, E. & Shim, J. (2020). Encouraging collaboration and building community in online asynchronous professional development: Designing for social capital. *International Journal of Computer-Supported Collaborative Learning 15*, 351–371.