The role of simulations for supporting professional growth: Teachers' engagement in virtual professional experimentation

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Abstract: There is growing interest in the field of education for leveraging emerging digital technologies to support teachers' learning in online or blended settings. This paper builds on Clarke and Hollingsworth's (2002) *Interconnected Model of Professional Growth* by investigating an alternative instantiation of *professional experimentation*. In particular, we examine the Story*Circles* model of professional development (Herbst & Milewski, 2018), which ushers teachers into a simulated type of professional experimentation to support teacher growth through the design and improvement of lessons using storyboards. In that context, we investigate how Story*Circles* enable teachers to experiment professionally in a virtual space. Focusing on the experiences of two secondary mathematics teachers, we illustrate how the Story*Circles* processes of scripting and argumentation were associated with teacher growth. We discuss how the Clarke and Hollingsworth (2002) *Interconnected Model of Professional Growth* can be useful for the design and study of simulated professional experimentation.

Keywords: Technology-Mediated Professional Development, Practice-based Pedagogies, Professional Experimentation, Professional Growth, Inservice Teachers

The role of simulations for supporting professional growth: Teachers' engagement in virtual professional experimentation

In the field of teacher education, there is growing interest in using practice-based pedagogies to help teachers learn to carry out new instructional practices. Such interest centers on the assumption that individuals are best positioned to learn new instructional practices by actively engaging with practice itself (Ball & Cohen, 1999), including observing, studying, as well as approximating practice (Grossman et al., 2009). While many such experiences have traditionally been delivered in face-to-face clinical settings (Lampert et al., 2013), emerging digital technologies allow for the possibility of supporting teachers' engagement with practice-based pedagogies in online or blended settings. Herbst and colleagues (2016) explored the affordances of digital technologies for supporting practice-based pedagogies in teacher education, including describing how various uses of technology can help address the problems and support the practices of teacher education. But what mechanisms might support individual growth as teachers engage with those technologically-enhanced pedagogies? In this paper, we consider how a virtual environment—Story*Circles*—can support teacher learning from practice through professional experimentation (Clarke and Hollingsworth, 2002).

Clarke and Hollingsworth (2002) propose a model for describing teachers' professional growth. In that model, they represent four interconnected domains related to teachers' professional growth. They define the domain of ***practice****—in which teachers engage in professional experimentation*—as encompassing all facets of a teacher's professional activity. Their conception of professional experimentation consists of teachers' attempts to try new activities within that broad domain (p. 961). Considering the potential of technologically-

mediated teacher education, we wonder whether and how their model could accommodate teacher growth through professional experimentation in simulated settings, which we exemplify in this paper. As a contribution to an investigation of this question we examine teachers' interactions within a particular intervention, Story*Circles* (Herbst & Milewski, 2018), which we contend is a virtual case of professional experimentation.

Story*Circles* (Herbst & Milewski, 2018) is a form of online professional development that gathers teachers (using video conferencing and asynchronous forum software) to collectively represent how a lesson, built around a particular mathematical task, might unfold. As teachers script aspects of the lesson, a storyboarder works in the background, using online software to represent the scripted lesson in the form of a storyboard. The storyboarder shares and displays the storyboarded representation of the ideas for the teachers to visualize the lesson and argue about alternatives.

We posit that a Story*Circles* interaction embodies, albeit virtually, some of the characteristics of professional experimentation. First, Story*Circles* create a space for teachers to try out new instructional practices. Second, inasmuch as Story*Circles* provide an opportunity for teachers to script storyboards rather than teach actual lessons, those opportunities are virtual. Third, to the extent that Story*Circles* involve a group of practitioners reacting to each other's ideas, their virtual nature does not necessarily deprive the participants from what they would get in classroom experimentation: participating teachers still have to risk doing things that (other teachers might think) do not quite work and have to cope with responses and reactions from students in the virtual classroom (whose voices are animated by colleagues who bring in their knowledge of students to respond to experimentation moves). Given these characteristics, we

consider Story*Circles* as a virtual case of experimentation to further define and explore how this type of experimentation may support teacher growth. Using the *Interconnected Model of Professional Growth* (Clarke & Hollingsworth, 2002), we examine the interactions of two secondary geometry teachers who participated in a StoryCircle, each playing a crucial role in developing a storyboard. Based on the experiences of those two participants, we describe two possible mechanisms for teacher growth that might be observed when teachers engage in simulated professional experimentation.

Story*Circles* as a Simulation of Practice

Practice-based approaches aim to support teacher learning by centering teachers' experiences "in the tasks, questions, and problems of practice" through the use of records and artifacts of practice such as student work, video records of classroom instruction, or lesson plans (Ball & Cohen, 1999, p. 20). With the increased interest in developing practice-based approaches, scholars have begun to describe a variety of ways that such pedagogies might be used to develop common instructional activities and curricular materials for teacher education (Ball, Sleep, Boerst, & Bass, 2009; Grossman et al., 2009; Kazemi, Lampert, & Franke, 2009). Some of that work has focused on the ways in which practice-based pedagogies might be integrated with teachers' everyday experiences "with real students in real classrooms" (McDonald, Kazemi, & Kavanagh, 2013, p. 383). While such efforts can be quite compelling for providing mechanisms for teacher growth, some have continued to express doubts about the extent to which actual classrooms can serve educative purposes beyond the socialization of teachers into the typical schooling routines (see Ellis, 2010; Zeichner, 1981, 2012).

Some scholars have taken a different tack, investigating ways to engage teachers in practice-based pedagogies through the use of simulated environments (Amidon, Chazan, Grosser-Clarkson, & Fleming, 2017; Brown, Davis, & Kulm, 2011; Dieker, Hughes, Hynes, & Straub, 2017; Herbst, Chieu, & Rougée, 2014; Lampert et al., 2013; Shaughnessy & Boerst, 2017). For example, Lampert and colleagues (2013) describe rehearsals as a kind of simulated activity distinct from more typical run-throughs or microteaching found in teacher education courses. Lampert and colleagues describe how the simulated nature of the activity ensures that novice teachers have a chance to try on particular aspects of practice by trying aspects of it in these simulated settings—receiving feedback from the reactions within the simulated classroom before enacting them in a classroom. They also describe how the simulation provides the teacher educator the opportunity to shift between her role as a simulated student and a coach, compelling the group to consider and weigh alternatives and also providing more direct feedback.

We contend that Story*Circles* share many of the features ascribed to other forms of simulated practice. Story*Circles* is a form of professional education that builds on the knowledge of practitioners and engages them in collective iterative scripting, visualization of, and argumentation about mathematics lessons using multimedia environments (see Figure 1; Herbst & Milewski, 2018).

In Story*Circles*, teachers are provided with a mathematical task or instructional goal and asked to collectively create a storyboard representation of how such a lesson would unfold. To do this, the teachers engage in cycles of ***scripting*** events in the lesson—sharing the kinds of actions they envision the teacher to take as well as anticipating the ways in which students might respond.

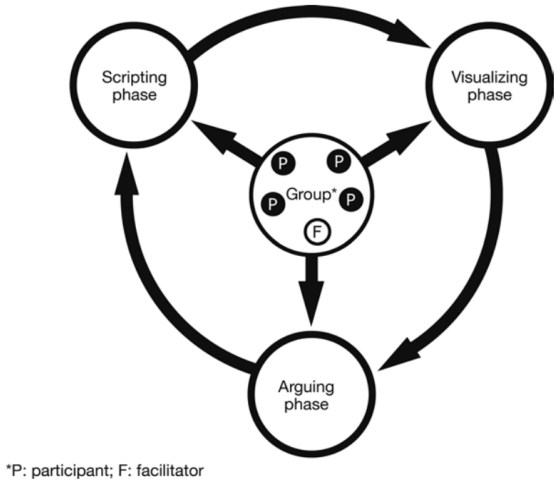

Figure 1. A simple representation of Story*Circles* (Herbst & Milewski, 2018)

In Story*Circles,* the feedback is facilitated not only by the reactions from individual participants but also by the visualization of the lesson in an online storyboard. Distinct from rehearsals (Lampert, 2013), each Story*Circles* participant scripts actions for both the teacher and students in a storyboard where cartoon characters in classroom settings play the role of teachers and students. Teachers' contributions are depicted in a storyboard and displayed for participants to view (see Figure 2). As a form of simulated professional experimentation, Story*Circles* differs from other kinds of simulations of practice because the various alternatives under consideration can be captured in storyboarded representations of practice that are both durable (i.e., unlike discussions which are ephemeral) and malleable (i.e., unlike video records of teaching).

A central component of the Story*Circles* process is the technology-mediated ***visualization*** of the lesson which is done with the ***Depict*** (Herbst & Chieu, 2011) storyboarding software. ***Depict*** is part of a suite of tools in the Lesson*Sketch* platform (www.lessonsketch.org) in which users drag and drop customizable graphic elements (e.g., users can select from a suite

of backgrounds for representing K-12 classrooms, move and change the orientation of furniture, or select characters' facial expressions) from a library onto a canvas to create representations of classroom practice. While some of our Story*Circles* have happened in face-to-face settings, with the storyboarder displaying his or her screen with a digital projector, the Story*Circles* interaction described in this paper took place in synchronous meetings using video conferencing and screen sharing software with follow-up asynchronous discussions that happened in online forums.

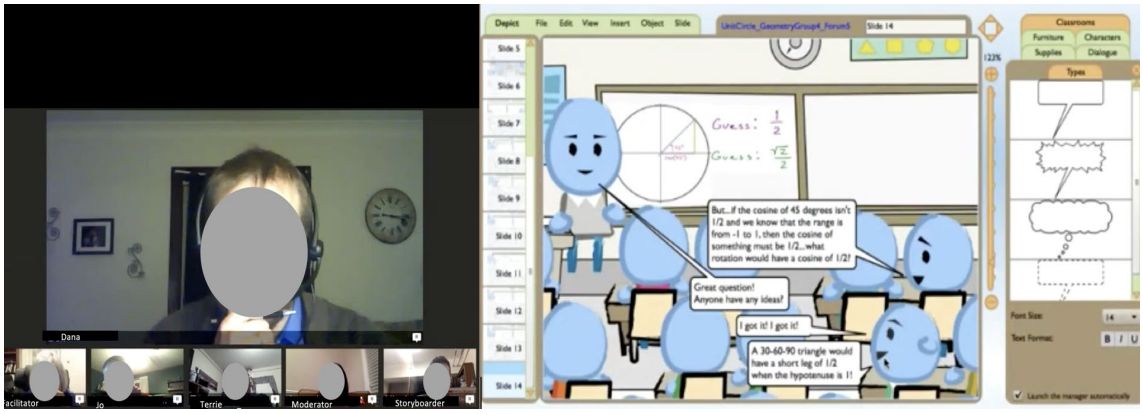

Figure 2. An image from a Story*Circles* meeting hosted on video conferencing software. The screenshot of the *Depict* software on the right hand side of the figure and all the graphics are © 2017, The Regents of the University of Michigan, used with permission.

While the storyboarding can be done by participants (see Chen, 2012) or by the facilitator, in this project we supported participants by employing a storyboarder (a non-participant who had experience using the software) to represent participants' contributions. The storyboarder usually asking clarifying questions of participants—for example asking where they wanted the teacher to be standing during a particular portion of the lesson. On other occasions, the storyboarder stayed intentionally quiet—representing only a minimum of what they heard and waiting for participants to request more details.

Participants' contributions and the subsequent depiction of those contributions are sometimes met with alternatives by other participants. To collectively decide on which alternatives should be included in the common storyboard, the group shifts into a cycle of ***argumentation*** by offering various forms of justifications for the given alternatives. Once the group resolves the argument, the group moves back into scripting the next bit of the lesson or revising the segment they had just discussed. While Story*Circles* facilitators generally play a fairly neutral role by letting the participants direct their own activity through the collective development of the storyboard, the interaction could be customized to allow for the facilitator to play a role more like that of the teacher educator in a rehearsal, shifting back and forth between playing the role of a coach and playing a part in the simulation. In this section, we have described Story*Circles* as a kind of simulation of practice, not unlike other forms of simulation. In the next section, we introduce a theoretical framework useful for accounting for teachers' professional growth within such settings.

Theoretical Framework

Clarke and Hollingsworth (2002) propose a model for professional growth that frames teachers' growth as the result of the interaction between four separate domains of teachers' professional worlds (see Figure 3). The *external domain* encompasses factors outside the teacher, such as information presented during a professional development event or the curriculum adopted by the school. The *personal domain* includes the knowledge, beliefs, and dispositions an individual teacher has. The *domain of practice* encompasses all facets of a teacher's professional activity, including the instructional activities that the teacher and their students engage in on a

daily basis. Lastly, the *domain of consequence* includes academic, socio-emotional, and other outcomes teachers attend to during the school day (p. 951).

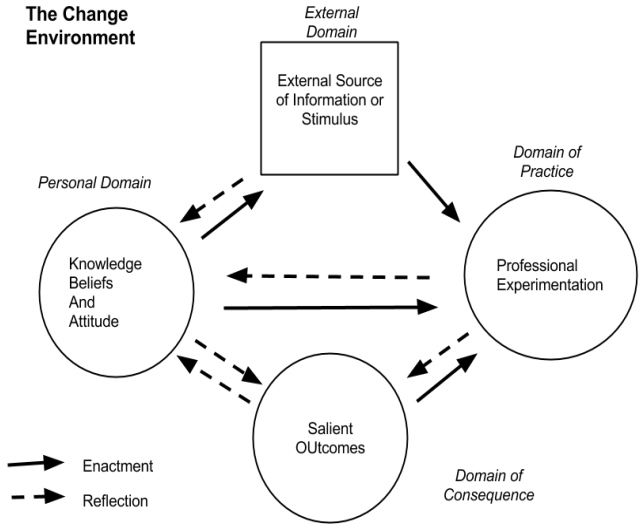

Figure 3. Interconnected Model of Professional Growth from Clarke and Hollingsworth (2002)

These separate domains are connected through the processes of *enactment* and *reflection*. Clarke and Hollingsworth (2002) claim that each of these individual domains can impact the other domains as teachers engage in new kinds of enactment or reflection on teaching, eventually enabling teachers' professional growth. For example, the adoption of a new textbook (i.e., change in the external domain) may influence the content that a teacher covers (i.e., change in the practice domain through enactment) which may help a teacher develop a new understanding of a mathematical idea (i.e., change in the personal domain). Conversely, a teacher's experimentation with new instructional practices (i.e., change in the domain of practice) may have a positive impact on students' motivation to learn (i.e., change in the domain of consequences) and through reflection on these changes, teachers' knowledge about teaching students may shift as well (i.e., change in the personal domain). The interaction between domains

provides teachers with opportunities to acquire new knowledge, skills, and dispositions while simultaneously providing an impetus for teachers to engage in professional experimentation. As teachers engage in such experimentation, they have opportunities to see the outcomes of their actions; this cycle has been shown to have direct and mediated impacts on teachers' knowledge that feed back into changes in teachers' practices (e.g., Voogt et al., 2011).

We were interested in considering the extent to which this *Interconnected Model of Professional Growth* can account for the ways in which professional experimentation in a simulated setting can help support the development of teachers' knowledge, skills, and dispositions. We define professional experimentation in simulated environments to be any kind of experimentation that takes place in settings distinct from an actual classroom involving actual students. Professional experimentation in simulated settings engages teachers in approximating (Grossman et al., 2009) elements of practice in environments that are mediated by either individuals playing the role of students (e.g., rehearsals; Lampert et al., 2013) or virtual representations of classroom settings (e.g., TeachLivE or Second Life; Dieker et al., 2017; Brown et al., 2011). We see these simulated forms of professional experimentation as offering immersive spaces for teachers to: (1) experiment with new kinds of instructional practices and (2) pause an experimentation to reconsider decisions in light of numerous alternatives. They can do that without having to simultaneously face the risks that accompany experimentation in actual classrooms (the domain of consequence).

`In this paper, we investigate the extent to which Clarke and Hollingsworth's *Interconnected Model of Professional Growth* can be useful in investigating the learning that may be accomplished in the context of Story*Circles* as a type of simulated professional

experimentation. To make use of the *Interconnected Model of Professional Growth*, however, we need to first identify where professional experimentation in a simulated setting might fit in the *Interconnected Model of Professional Growth.* From our perspective, there are two reasonable places such an activity might fit. The first is in the external domain, where such activities might act as a stimulus for changes in teachers' knowledge, beliefs, and dispositions or changes in the domain of classroom practice. We suggest this might be a reasonable place for activities such as rehearsals, simulations of practice, or Story*Circles* as aspects of such activities could be seen as "outside the teacher's personal world" (Clarke & Hollingsworth, 2002, p. 951) and in that way similar to information presented during a professional development. On the other hand, as teachers engage in scripting how the task would be handled in the classroom, they have the opportunity to experiment with new instructional practice in the simulated setting, moving it into the domain of practice. According to Clarke and Hollingsworth (2002), the domain of practice "is conceived as encompassing all forms of professional experimentation, rather than just classroom experimentation" (p. 950). Given that definition, it is reasonable to argue that the scripting, visualizing, and arguing that constitute Story*Circles* can serve as professional experimentation (albeit in a simulated setting) just as much as classroom practice does in the *Interconnected Model of Professional Growth*. In the end, the placement of simulated forms of professional experimentation in the personal domain has the added advantage of enabling us to open up the black box of simulated settings for supporting teacher growth. For our purposes, we elect to frame simulated professional experimentation as a specific kind of professional experimentation achieved within the domain of practice.

Research Question

We aim to describe and explain the ways in which teachers' engagement in simulated professional experimentation can support teacher growth. In particular, we examine the Story*Circles* model of professional development as a kind of virtual professional experimentation ushering teachers and facilitators into a simulated space to support teacher growth through the design and improvement of lessons. In that context, we ask what kinds of evidence of change in the personal domain can we see in instances of experimentation in Story*Circles*.

Methods

The research efforts described in this paper grew out of a professional development project entitled *EMATHS through Lesson*Sketch *Story*Circles.[1] In that project, we aimed to investigate the potential for the Story*Circles* model of professional development to support teachers' use of instructional tasks developed previously as part of the EMATHS curriculum and professional development project. The lead developer of the EMATHS project had been dissatisfied with the implementation of those mathematical tasks: some teachers had been implementing the tasks as intended, others in ways quite different than what she and the other project staff had imagined, and still others had chosen not to implement them at all. She saw the potential for the Story*Circles* model to organize teachers—located throughout the state, who had previously experienced the EMATHS curriculum and professional development—into online

[1]EMATHS (Embracing Mathematics, Assessment, Technology in High School) through Lesson*Sketch* Story*Circles* was an Mathematics Science Partnership project awarded to Deborah Ferry at the Macomb ISD and funded through the State of Michigan. The authors participated in this project through a subcontract to the University of Michigan. All opinions in this paper are those of the authors and do not necessarily represent the views of the organizations.

professional learning communities focused on supporting teachers' use of particular EMATHS lessons. The Story*Circles* would have teachers who taught the same lessons in different institutional contexts bring their experiences to create rich documentation of how these particular lessons could unfold in order to support more consistent implementation across classrooms that could lead to more permanent changes in teachers' instructional practices.

The Story*Circles* interactions we describe in this article took place among four secondary inservice geometry teachers (see Figure 4), along with a facilitator and a storyboarder, between the months of January and March of 2016.

Teacher Variables			School Variables				
Name	Years Teaching	Locale	Student Population	School Status[2]	School Ranking in the State	Economically Disadvantaged Students	Minority
Terrie	23	Rural	< 100	None	1st Decile	58%	6%
Dana	12	Rural	>300	None	4th Decile	43%	8%
Tracey	10	City	>700	HPS	1st Decile	65%	73%
Joe	20	City	>700	HPS	1st Decile	65%	73%

Figure 4. Descriptions of participants and their current school assignments.

The data we selected for analysis for this paper comes from a series of interactions focused on the collective construction of a storyboard depicting how a lesson focused on a Unit Circle task from the EMATHS curriculum might unfold in a 10th grade geometry class. These interactions

[2] The data comes from the larger *EMATHS through LessonSketch StoryCircles* project that gathered teachers from a variety of public school contexts, including those working in high-priority schools (HPS)—a classification of schools defined by the State Department of Education according to a formula that takes into account a variety of factors including student achievement on state tests, achievement gap, and school improvement.

took place across two synchronous video conference meetings and seven follow-up forum discussions. Across the entire year, the amount of time participants spent interacting within the professional development varied (see Figure 5).

Teacher	Meetings Attended (Out of 6)	Meeting Contributions	Forum Contributions	Forum Contributions with a Depiction	Time Spent in Forums (hours)
Terrie	6	159	222	1	113.9
Dana	6	181	304	40	52.9
Joe	6	182	15	0	8.0
Tracey	3	57	3	0	3.42

Figure 5. Descriptions of 3 EMATHS Teachers' Engagement Across the Year

Within that larger group, we elected to focus our analysis on the interactions of two participants, Dana and Terrie. As can be seen in Figure 4, Dana and Terrie came from somewhat similar contexts (both working in small rural remote schools not identified as High Priority Schools by the State Department of Education). Further, Dana and Terrie spent considerably more time than Joe and Tracey in the forums, with Dana making more contributions than Terrie and Terrie spending more time than Dana (see Figure 5). The data gathered include video and audio recordings of the synchronous sessions, forum entries, the collectively-created storyboard, and summary comments[3] provided by the participants about the professional development and the lessons they created.

Our analysis of Story*Circles* interactions began with a creation of field notes, recorded by researchers on the project. Next we segmented the field notes using interactional analysis,

[3]Summary comments collected in the contexts of a survey and focus group interviews with all teachers, conducted by the project evaluator.

identifying changes in participants' focus (Lemke, 1990; Jordan & Henderson, 1995). Using the segmented field notes, we identified portions of the video of particular interest for transcription, including the bulk of the video, but leaving off segments focused on more logistical issues such as more general housekeeping or tutorials about how to use the video conferencing technology. Our analysis of the storyboards were limited to the initial storyboard the group considered during the synchronous meeting and the final storyboard the group completed, where we compared the two artifacts for changes across the entire storyboard (such as additional frames being added) as well as changes within particular frames (such as revisions to work on the board).

Insights

In the subsections that follow, we share some of the preliminary insights we have gained about the potential of Story*Circles* for supporting teacher growth. We begin by sharing evidence about teachers' growth we have gained by examining participants' artifacts and interactions. Following that, we describe the experience of two participants that took on different kinds of roles in the Story*Circles* to illustrate various ways that teachers might engage in simulated professional experimentation.

Evidence of growth in the interaction and artifact

One of the ways that we can understand teacher growth in the context of a Story*Circle* is by considering changes in the interaction among and artifacts produced by the participants. In the days prior to the first video conference discussion of the Unit Circle Lesson,[4] Dana had taken it upon himself to script a portion of the lesson through the creation of several storyboard frames

[4] The Unit Circle Lesson came after the group had already collectively constructed two other lessons.

for the group to consider. The facilitator reacted to Dana's storyboard frames by elaborating on the original intentions of the Unit Circle Lesson saying "this whole unit circle thing is really the introduction to students' understanding of sine and cosine as if they've never seen it before" (Facilitator, M4S3, 0:03:44). That is, the intention of the task was that students would engage in an exploration of the Unit Circle without relying on previously developed trigonometric ratios.

This information came as a surprise to Dana as his depiction represented his assumptions about how this topic is typically taught. Dana assumed that students are usually first introduced to the trigonometric functions as the ratio of the sides in right triangles (usually referred to as the right triangle trigonometry or trigonometric ratios; taught immediately after the introduction of special right triangles and sometimes taught in conjunction with the mnemonic SOH-CAH-TOA). At some later point in the year, students are typically asked to use those trigonometric ratios in the context of an exploration of the Unit Circle to extend to a more general definition of the trigonometric functions. In responding to the facilitator, Dana described why his storyboard aligned with this common trajectory, saying "That was—I guess—where I was confused … in my normal teaching, I would have done right triangle trig before I actually go into the Unit Circle" (M4S3, 0:05:11). The difference between the lessons envisioned by the facilitator and by Dana is not only obvious in Dana's comment, but can also be understood by examining the storyboard frames constructed by Dana (see frames 3, 5, and 11; Figure 6) that presume students will use their prior knowledge about special right triangles and right triangle trigonometry.

Dana was not the only one surprised by the facilitator's suggestion. Prior to the meeting, Dana had asked others for feedback about the storyboard he was constructing in preparation of the meeting saying:

> I usually start by drawing a Unit Circle and then slowly putting the special triangles In:30-60-90, 45-45-90, then 60-30-90. After getting the coordinates based off the special triangles, I usually then discuss the cosine and sine relationship. So, does anyone have another way to start this? (UCF1, 2016-01-17, 15:35:43).

A few days later, Terrie responded to Dana's question by sharing:

> I've always taught it as the ratio. I'm not particularly fond of that method though for a couple of reasons. One, it's a quick and dirty way out that does not really give the students an in-depth understanding. Two, it's more formulas that they have to learn (UCF1, 2016-01-22, 10:14:27).

Thus, neither Terrie nor Dana imagined implementing this lesson without the trigonometric ratios. Rather, they were wondering whether the teacher in the storyboard should ease the students into the trigonometric ratios with the use of special right triangles, or jump right to the ratios. Further, after the facilitator reiterated the goal of the lesson, the other teachers in the group also seemed uncertain—spending quite some time clarifying that the change proposed by the facilitator included bypassing the introduction of trigonometric functions in the context of right triangle trigonometry until they could be introduced within the context of the Unit Circle and altogether skipping the introduction of the SOH-CAH-TOA mnemonic.[5] The difference between Dana's storyboard and the suggestions of the facilitator along with his and others reactions to the facilitator's ideas all suggest that the facilitators' perspective on the purpose of the Unit Circle lesson originated from the external domain for these participants.

In the two months that followed that meeting, participants spent a total of two hours together in synchronous video conferencing meetings and several hours connecting across a series of asynchronous forums. During that time, the participants collectively produced 7

[5] For an argument justifying this approach over the more typical sequence, see Weber (2008) or Moore & LaForest (2014).

additional versions of the story (an amalgamation of revisions made by the storyboarder during the meetings and 17 new versions of the storyboard submitted by participants in the forums; 16 of those new versions were submitted by Dana).

The difference between the final version of the Unit Circle Lesson and the one Dana had originally represented can also be understood by examining a handful of the storyboard frames (see Figure 7). In the first few slides, it becomes clear that the only knowledge being used is that of circles and rotations. By frame 5, students are introduced to a new way of defining the *x*- and *y*-coordinates in terms of the trigonometric functions, cosine and sine. Using their knowledge of circles, student are asked to find the sine and cosine for angles of 0, 90, 180, and 270 degrees. As the lesson unfolds further, the students begin to make more general claims about the values that sine and cosine can take on (namely, they range from negative one to positive one). The lesson concludes with the construction and verification of hypotheses about the value of sine and cosine for special angles, such as angles of 30, 45, and 60 degrees. The lesson is quite different than the one Dana and others had originally supposed they would be representing where knowledge of special right triangles was taken as prerequisite.

More importantly, the participants were central in the construction of the storyboard, rather than it being constructed by the facilitator. For example, even after participants were supposed to have been turning their attention to the next lesson, Terrie continued to worry about the revision of the smaller details of the Unit Circle Lesson, saying:

> To continue I'd suggest the students work together to map a 30-60-90 triangle in the first quadrant. Begin with the 30 degree vertex at the origin with an example. Then have them graph it with the 60 degree angle at the origin on their own. After, doing that, I'd ask if this links to, or flat out answers, any prior questions. During this line of questioning, some student would probably ask about sine having a value at 1/2, and a different student

> will point out that we did that in the example. Perhaps outside the scope of the lesson, but I suspect it will come up (UCF1, 2016-03-05, 09:16:17).

The participants continued engagement even when the group had moved on to focus on a new lesson gives a sense of both how invested participants were with the ideas represented in the storyboard and how central they were in the construction of the final.

Scripting as a means for professional growth

Throughout the Story*Circles* process, Dana often took on the role of the enthusiastic scriptor, initiating and leading the group's engagement with the storyboarding process. In this section, we examine Dana's experiences, using the *Interconnected Model of Professional Growth* to focus on how professional growth can result from engagement in the phases of scripting from the Story*Circles* model (see Figure 8a). After taking time to clarify the intended

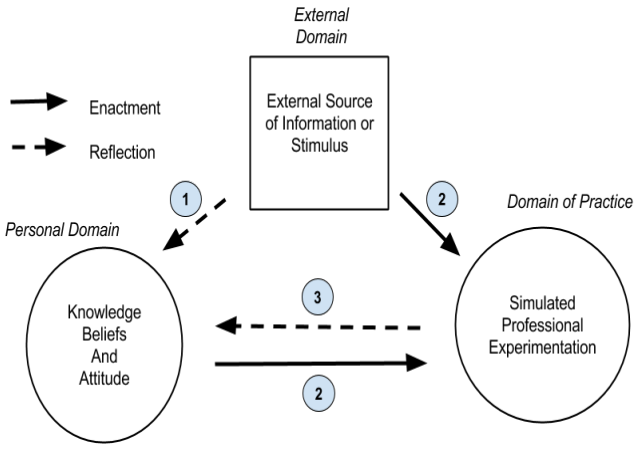

Figure 8a. Top portion of the *Interconnected Model of Professional Growth*

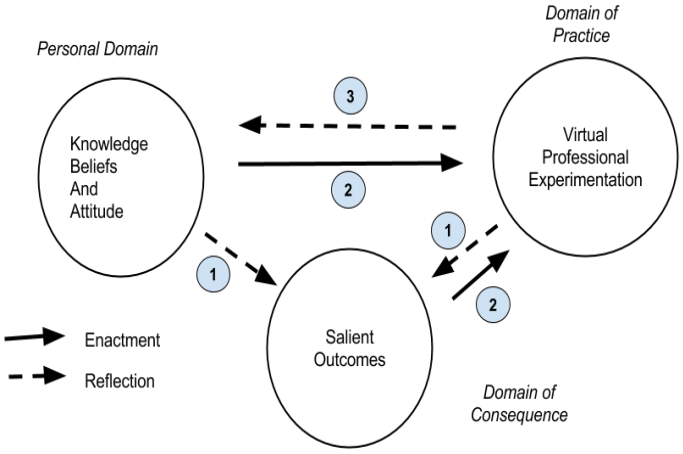

Figure 8b. Bottom portion of the *Interconnected Model of Professional Growth*

purposes of the lesson, the facilitator checked in with the participants, asking if they would be willing to give the lesson a try. While Dana likely had the most to lose in going along (as he had

already invested time scripting a portion of the lesson), he was the first to declare at least a willingness to engage in a virtual experiment using the new information from the external domain by saying with a chuckle, "I can do anything in a depiction" (M4S3, 0:06:35). The other two participants, however, continued to express uncertainty about the idea. Furthermore, several minutes after Dana's initial expressions of willingness, he expressed difficulty engaging in the thought experiment, saying:

> I'm willing to give it a try …. I'm just processing 'cause like ... it's a little bit different and it's like wow … hmm … I mean it's kind of what I've done with my—I mean—my advanced math class because they're typically just reviewing the idea and they never really understand what the Unit Circle is. So I'm just trying to figure out how - I mean I'm just trying to see how that's all coming together in my mind but it's like dumping like a big thought on my brain and I'm pondering it (M4S3, 0:09:03).

Dana's comment gives us some sense of how the various domains from Figure 8a work together. Reflecting on the ideas from the facilitator (process labeled "1" from the external to the personal domain in Figure 8a), Dana was growing aware that the enactment[6] of those ideas in a simulated lesson (process labeled "2" from the external and personal domains to the domain of practice in Figure 8a) would demand a different kind of knowledge of the task. Further, while he had taught similar lessons to his advanced mathematics class, his reflection (process labeled "1" from the external to the personal domain) seems to indicate that he was doubting whether his own experiences would be helpful for the present activity. His doubt seems to stem from the fact that those experiences made use of students' previously-developed knowledge that would not be guaranteed in this new scenario, and that his previous experiences had led students to a

[6] These enactments are in the context of a simulation, which Grossman et al. (2009) might describe more as an *approximation* than as an enactment. We preserve Clarke and Hollingsworth (2002) language during the analysis to be consistent with their model.

superficial understanding of the Unit Circle. So at this point, Dana seems to be trying to figure it out but finding his own personal resources potentially insufficient.

Upon hearing Dana's difficulties anticipating how the Unit Circle Lesson might unfold, the facilitator took some time to outline the mathematical arc of the task as intended: starting with rotating a point around the Unit Circle, identifying the *x*- and *y*-coordinates of each of the points as connected to particular arcs of the circle and also right triangles, and dilating the Unit Circle to demonstrate the role of the hypotenuse in the sine and cosine ratios (i.e., dividing the opposite or adjacent legs of the triangle by the hypotenuse as equivalent to scaling the circle back to the circle with unit one). It also turns out this move was a crucial turning point for enabling participants to engage in the activity of enacting the Unit Circle Lesson (i.e., to move from process "1" from the external to the personal domain to process "2" from the external and personal domains to the domain of practice in Figure 8a). After the facilitator's elaboration, Dana shifted in the direction of accommodating the curricular change, saying:

> Yeah, I think I'm actually liking the idea the more I think about it because I'm trying—I'm continuously trying to point out to my students that right triangles and circles are—there's this magical relationship between the two and trying to help them get that a little bit better. I've always gone with the triangle to the circle but I guess I can see going from the circle to the triangle might actually make a little bit more sense (M4S3, 0:11:01).

In the moments following Dana's acceptance for the new approach, the facilitator again checked for consensus from other group members. The other participants indicated they would be willing to give the lesson a try.

In the remaining portion of the video conference meeting, Dana and the other participants began the process of engaging in virtual experimentation using both the external domain information from the facilitator and their own knowledge and beliefs (the processes labeled "2"

from the external and personal domains to the domain of practice in Figure 8a). We think it is key that Dana's move to accommodate the task came after the facilitator laid some of the groundwork for the change by scripting some elements for how the lesson might unfold. He manages this, in part, by merging resources from both the external and personal domains to engage in iterative stages of scripting and visualizing (see Herbst & Milewski, 2018); this represents engagement in both processes labeled "2" in Figure 1. However, Dana seemed to be the member that took on the most ownership of engaging in the processes of scripting.

Dana's willingness to take more of a lead on the scripting of the new lesson grew stronger as the group moved beyond the meeting into the weekly forums. In the week following the video meeting, Dana offered five revisions to the storyboard and sought feedback from peers for each one. For example, in one posting, Dana added two new storyboard frames and commentary saying "Defining Theta and Cosine and Sine. These two slide work on definitions" (UCF3, 2016-01-30, 17:23:20). Following this posting, both the facilitator and Terrie responded to Dana's request for feedback (a point we discuss in more length in the next section). For the moment, we pause to make two crucial observations. The first is that the two frames suggested by Dana are very similar to frames 4 and 5 from Figure 7—the final storyboard. While it would take more room than we have here to illustrate the elements of likeness between the two starting and ending storyboards, we simply note that this similarity between participants' suggestions and the final storyboard helps us to understand the ways in which individuals' personal resources helped shape the final collectively developed storyboard. Second, we note that the frames are not identical, and were modified following the feedback Dana received--the mathematical representation on the board was refined.

We see evidence of Dana's personal growth within his changing interactions—moving from one professing difficulty imagining a lesson as envisioned by the facilitator to one taking lead on scripting elements of the storyboard. We also see evidence of his growth in the shifts in the storyboard itself—moving from a lesson that presumed students' familiarity with the trigonometric ratios to a lesson that used the unit circle to introduce the trigonometric ratios. As such, we argue that Dana's participation in the role of scriptor illustrates one mechanism for teachers' professional growth through engagement in professional experimentation.

Arguing as a means for professional growth

As the group began to visualize how the lesson might unfold, Terrie participated in ways markedly distinct from Dana, taking on the role of a respectful dissenter. In this section, we examine Terrie's experiences, using the *Interconnected Model of Professional Growth* to understand how professional growth can result from engagement in the phases of argumentation from the Story*Circles* model (see Figure 8b). Like Dana, Terrie had expressed a willingness to go along saying "Well I'll give it a shot and I will have an open mind" (M4S3, 0:19:02). However, it was less clear that Terrie was yet convinced of the value for the approach. In a particularly poignant interaction, Terrie sat quiet for some time while the other teachers and facilitator had begun to visualize how to begin the Unit Circle exploration. Specifically, the group had decided that the teacher would start class by defining theta as the angle of rotation of the vector (1,0) which is rotated about the origin and also defining cosine and sine as corresponding to the x- and y-coordinates of the point that traces the unit circle. Next, the group scripted the teacher's subsequent actions to ask the class to discuss the values for the sine and cosine of the multiples of 90 degrees. At this point in the interaction, Terrie asked the facilitator

to clarify whether the lesson would begin by asking students to examine instances in which the hypotenuse of a special right triangle would align with the four cardinal directions (north, south, east, and west). The facilitator reacted by reminding Terrie that this approach gave less attention, in the beginning, to triangles saying, "So when I'm saying ninety degrees I'm still talking about theta and theta is defined as the point one zero rotated around the origin" (M4S3, 0:22:28). Terrie revoiced her contribution using his own frame of reference saying, "Okay, so you're talking about the cardinals, okay" (M4S3, 0:22:40). The facilitator responded:

> Right, and remember you can rotate—you know—three-sixty to seven-twenty, but what you're trying to reinforce here is what is theta, what is the center of rotation, and you're your original definition of what's cosine and what's sine. Those three things are really crucial and that's why I'm kinda pushing for sticking with ninety before you get a special right triangles. (M4S3, 0:22:43)

This time Terrie reacted with an argument against the direction of the storyboard, saying:

> I understand where you're going. The way my thought is, I would consider those to be a degenerative[7] triangle case. So I would bring them up—I probably wouldn't bring them up first, but I do understand your rationale for doing it. And if you feel that strongly about it, I'm willing to admit that you've done this and I haven't. So you know I can give that a shot, but I don't ever start with degenerative case in anything else, so. (M4S3, 0:23:30)

Terrie, with a sheepish grin[8], followed this contribution by clarifying that he wasn't intending to give the facilitator a hard time.

Across Terrie's participation, we see him offering something quite different than other participants. Rather than scripting elements of the collective experiment, Terrie offers an

[7] The actual word used in mathematics is *degenerate*. Degenerate triangles are those in which all three vertices are collinear. They are recognized as special cases because they have properties that are not generalizable to other triangles.

[8] The use of humor was a fairly normal part of this group's interaction as was Terrie's positioning of himself as one who raised serious arguments about the direction of the group's decisions.

argument that illustrates how the domain of consequence might shape the group's scripting activities (i.e., the process labeled "2" from the domain of consequence to the domain of practice in Figure 8b). In particular, we see him offering an important disciplinary consideration about whether it is best to start an explanation of a concept using a degenerate case (generally something teachers avoid doing because of the peculiar nature of such cases). This kind of participation, namely pushing back on the group's decision, was characteristic of Terrie's engagement in Story*Circles*.

In a later forum, Terrie expressed a concern about the group's collective decision to abandon the use of the SOH-CAH-TOA mnemonic. In a particularly long post, he wrote:

> To me, *already knowing the definitions*, SOHCAHTOA is simply a mnemonic that helps me recall them quickly … I also want them to be able to finish their SAT in the time allotted (Yes, I hate teaching to the test, but it's an unfortunate reality for me) … FWIW [For what it's worth], This is one of the reasons I've been staying quieter in this thread than in some others. I don't feel my suggestions have as much value here as I'm not 100% sold on this approach (in a geometry sequence)" (UCF5, 2015/02/16; 19:56:43).

In this example, we see that Terrie has some uneasiness about his ability to contribute to the group's experiment. However, we see Terrie contributing an argument for the group's scripting, in the form of approximation from the domain of consequence and his personal experiences (thus engaging in the dual processes labeled "2" from the personal and consequences domain to the domain of practice in Figure 8b). The absence of SOHCAHTOA in the script evoked an argument from Terrie against the collective experimentation—namely Terrie suggested that such actions have negative consequences for students' preparedness to pass the SAT.

After Terrie's lengthy post, the facilitator reminded all of the participants that they had agreed to work on a version of the storyboarded lesson that introducing Cosine and Sine

relationship through the unit circle rather in order to discover the ratios rather than using the SOHCAHTOA mnemonic. (UCF5, 2015/02/16, 20:08:28). The facilitator faced a dilemma between honoring Terrie's idea by allowing for some uptake of it into the storyboard and honoring the original intent of the lesson as framed by the EMATHS team. Given the dual nature of the storyboard medium, being both durable and malleable, another option the facilitator could have leveraged would have been to allow the storyboard to branch, enabling Terrie to represent his ideas for consideration while not losing track of the primary branch of the story.

Within minutes of the facilitator's posting, Terrie responded by admitting difficulty reflecting on salient outcomes of the lesson, writing, "I am simply having a hard time visualizing how the class would react to this because I'm trying to justify it myself" (UCF5, 2015/02/16, 20:14:13). Terrie's comments give us some sense of how the various domains from Figure 8b work together. Reflecting on the ideas of the group as visualized in the professional experimentation, Terrie was growing aware that the approximation of students' reactions to those ideas would demand a shift in his personal beliefs about the value of the lesson (see process labeled "3" from the domain of practice to the personal domain in Figure 8b). While the engagement in scripting supported the group's initial development of the lesson, the engagement in argumentation enabled the group to collectively vet and improve the lesson.

Other indicators of professional growth

Stepping back from the interactions during the first year of the project, we see other kinds of evidence that despite the differences in the ways they were interacting, both Terrie and Dana grew across the project. For example, both teachers elected to implement this particular lesson with their students in both years of the project. Also, both teachers had positive things to say

about their experience in Story*Circles* in general, and in the development of the Unit Circle lesson in particular. In the final Unit Circle forum, Terrie signs off by writing:

> I know this is off topic for the forums, but I'ma [sic] gonna say it anyway. I've appreciated this group more than any district PD I've ever had to sit through. This, more than anything else, has applied directly to what I'm teaching. Most directed PD has been —well, fairly worthless. Thanks one and all for your inputs over the last few years. (2017-04-15 18:07:01)

Also in the final project survey administered by an external evaluator, both teachers identified the Unit Circle storyboarded lesson as one of three lessons (from a total of 8 geometry lessons) that should be shared in the library of EMATHS lessons for teachers across the state. When prompted for a rationale for the lesson's inclusion, Terrie said "I feel it was well defined and a worthy addition" (2017-03-29 Q38) while Dana said "This lesson helps teachers to move away from simple SOHCAHTOA and move to an understanding of trig" (2017-04-17 Q38).

Discussion and Conclusions

In this paper, we have documented the experiences of two participants who engaged in Story*Circles* in markedly distinct ways. Using the *Interconnected Model of Professional Growth*, we have illustrated how each of those experiences can enable participants' professional growth by precipitating the kind of realizations that ordinarily come from classroom experience. In particular, the professional experimentation that happens in the simulated space of Story*Circles* becomes the main vector connecting the professional development goals (i.e., the external domain), the participants' beliefs, knowledge, and dispositions (i.e., their personal domains), and the possible outcomes of the proposed instructional activities (i.e., the domain of consequence).

One of the implications of this work is that the *Interconnected Model of Professional Growth* can be useful for understanding how teachers grow professionally while engaged in

simulated professional experimentation. The characteristics of the *Interconnected Model of Professional Growth*, including its non-linear, flexible structure, make it a particularly useful tool for identifying various kinds of change sequences, such as the ones featured across Dana and Terrie. It could also be useful for drawing comparisons across different forms of simulated professional experimentation. That said, our use of the *Interconnected Model of Professional Growth* was not without its challenges. Perhaps the most salient was the difficulty we experienced in placing the activity of simulated professional experimentation in just one of the domains, as Clarke and Hollingsworth (2002) were able to do with professional experimentation in the classroom. This difficulty points to some uneasiness assimilating simulated professional experimentation within the domain of practice, perhaps suggesting that a modified version of the *Interconnected Model of Professional Growth* might better account for the multiple resources that play a role in supporting teachers' professional growth.

A second implication of the work is the potential of the Story*Circles* approach (Herbst & Milewski, 2018) for supporting growth across teachers taking different kinds of stances towards the external domain. For some time now, there has been a growing consensus (see Richardson, 1994) that the field needs to develop new ideas about teacher change that avoid the two extremes of a top-down perspective on change (as something coming from the external domain) and the bottom-up perspective on change (as something that stems naturally out of teachers' own personal domains). As exemplified across these two very different kinds of participants (one an enthusiastic scripter, one a respectful dissenter), we see the Story*Circles* approach as creating space for a middle ground. Story*Circles* creates a space where teachers are supported to grow professionally in two distinct ways: by experimenting with ideas from the external domain, and

by bringing those ideas under the scrutiny of their own knowledge and experiences stemming from the personal domain.

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