Using an analytic model to gauge the potential of innovative pedagogies of approximation in mathematics teacher education

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Abstract: In order to leverage pedagogies of approximation to improve teacher education, educational researchers must first tackle the methodological question "*How can we determine the potential of pedagogies of approximation for supporting the growth of prospective teachers' knowledge and practices for teaching?*" In this paper , we offer a model called the *Dual Action Cycles of Approximations of Practice* for identifying the pedagogical practices made available to pre-service teachers within various approximations of practice and describe its use to empirically investigate the potential of Story*Circles*—a facilitated process of collaboratively representing a lesson using a multimedia storyboarding tool. We illustrate ways that the *Dual Action Cycles Model* was used to make observations of pre-service teachers during Story*Circles.* A key feature of the model is that it provides a bi-focal perspective on both the preactive and interactive phases of teaching, which help bring into focus the interdependent nature of these two phases. We close by suggesting that the development of new forms of approximation needs to be accompanied by research frameworks capable of investigating the potential of these various innovations.

Keywords: Teacher Education, Practice-based Pedagogies, Approximations, Methodological Model, StoryCircles, Preactive, Interactive, Postactive

Statements and Declarations:

All authors contributed to the study conception, design, material preparation, data collection, and analysis. This draft of the manuscript was prepared by Amanda Brown and all authors contributed to and commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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"For the things we have to learn before doing, we have to learn by doing" - Aristotle

In the last twenty years, the notion that novice teachers need opportunities to learn by doing has gained considerable traction in the field of teacher education. This traction has been fueled, in part, by the introduction of the term *approximations of practice* (Grossman et al., 2009a)—referring to pedagogies that provide novices with opportunities "to engage in practices that are more or less proximal to the practices of a profession" (p. 2058). Since that time, there has been a growing number of mathematics teacher educators (MTEDs hereon) interested in designing and using pedagogies of approximation to improve teaching (e.g., Ayalon & Wilkie, 2021; Campbell & Elliott, 2015; Kavanagh et al., 2020). An important methodological question arises in such work, "How can we determine the potential of pedagogies of approximation for supporting the growth of prospective teachers' knowledge and practices for teaching?" In this paper, we describe the development of a model for identifying the pedagogical practices made available to pre-service teachers within various approximations of practice and use the model to empirically investigate the potential of Story*Circles*—a facilitated process of collaboratively representing a lesson using a multimedia storyboarding tool. Story*Circles*[1] was originally developed for engaging in-service teachers in collaboratively anticipating how a lesson could unfold. We wondered whether and how Story*Circles* would also be productive for supporting pre-service teachers (PSTs) to collectively engage in approximations of the interactive work of teaching. The model we offer was built as part of our efforts to address the opening question and takes into account the interdependent nature of the *preactive* and *interactive* aspects of the work of teaching—with the words preactive and interactive referring to the work of teaching that occurs before and during teaching respectively (Westerman, 1991). We argue that this dual-focus makes the model useful for exploring the potential of practice-based pedagogies for supporting PSTs'

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[1] When we use the term "Story*Circles*" we are referring to the Story*Circles* process and therefore treat the word as a singular rather than a plural.

growth. We start by first situating our study with a discussion of pedagogies of teacher education—providing the reasoning that motivated our decision to use Story*Circles* with a new population—namely PSTs.

1: The need for practice-based approximations in pre-service teacher education

Teacher education has historically been dominated by a focus on preactive aspects of teaching such as planning how to organise students' work to meet particular learning goals (Grossman & McDonald, 2008). This focus is problematic when one considers what we know about expert teacher planning—which takes into account not only features of a lesson such as the goals, task, and activity, but also the interactions within and between students' mathematical ideas, the mathematics at stake, and the task (Lampert, 2001). The lack of attention on the interactive work of teaching in PST preparation (Baldinger & Campbell, 2021; Campbell & Baldinger, 2020) has long been evident in novices' difficulties"attempt[ing] to improvise by constructing explanations on the spot or by organizing instruction around student questions and comments" (Borko & Livingston, 1989, p. 492). Other common challenges include novice teachers failing to establish classroom routines that can support them to engage in the kind of improvisational decision making needed for ambitious teaching (Lampert & Graziani, 2009)—teaching in ways that are responsive to students' mathematical ideas and contributions (Stein et al., 2008). While novices might learn to overcome such challenges within field-based work, many scholars have long argued that novice teachers need opportunities to develop critical instructional practices prior to their placements in actual classrooms (e.g., Ball & Cohen, 1999; Grossman & McDonald, 2008; Sweeney et al., 2018).

Ball and Cohen (1999) recommended a shift toward professional learning experiences centred on records of practice—where records of practice refer to "a collection of primary materials that represent core elements of an experience, an event or an interaction ... that permits one to retrieve and reconsider it at different points in time … and in various contexts" (p. 321, Ball et al., 2014). A decade later, Grossman and McDonald (2008) noted that TE often takes a rather academic stance towards the work of teaching. More specifically, they identified a trend of engaging novice teachers in what they called *pedagogies of investigation*—in which novices study "the complexity of teaching practice in some detail, including the use of case methods, video cases, and teacher inquiry projects" (p. 189). They advocated for an increased development and use of *pedagogies of enactment*—providing novices with "focused opportunities to experiment with aspects of practice and then learn from that experience" (p. 190). Similarly, Ball and Forzani (2011) argued mathematics teacher educators (MTEDs) should engage PSTs in "repeated opportunities to do the interactive work of teaching and to receive feedback - not just to talk about that work" (p. 19).

In response to these continuing calls, scholars have attempted to better define what could be meant by practice-based teacher education. Lampert (2010) considered various ways that teacher learning can be conceived of as happening *in*, *from*, and *for* practice: drawing its learning content *from* practice, developing its activities *in* (representations of) practice, and aiming at increasing capacity *for* practice. Lampert noted that the word *practice* (in English) is used in different ways, including: (1) *practice* as a verb synonymous with rehearse; (2) *practice* as a noun synonymous with professional practice; and (3) teaching as a collection of *practices* identified as the kinds of regular or habitual things teachers do. To avoid confusion, we borrow a British-English convention—using the term *practise* to refer to the verb (1), and the word *practice* to refer to the noun—reserving the plural form, *practices*, to refer to a collection of practices (3) and the singular form, *practice*, to refer to the professional practice as a whole (2).

Grossman et al. (2009a) undertook a cross-professional examination of practice-based pedagogies used in preparation of clergymen, teachers, and therapists. Of particular interest for this paper, they identified *approximation* as one of three commonly-used pedagogies of practice—which they described as providing novices the opportunity to carry out elements of practice in settings of reduced complexity. Grossman and colleagues (ibid) also found PSTs have fewer opportunities, compared with other professions, to engage in approximations of interactive practice. Problematically, many of the most challenging aspects of learning to teach lie within the interactive portions of teaching.

Another way that scholars have responded to these earlier calls is through the design of innovative forms of practice-based pedagogies for teacher education (Anthony et al., 2015; Amidon et al., 2017; Bannister et al., 2018; Cirillo et al., 2020; Crespo et al., 2021; Kochmanski, 2022). Some of those efforts have focused on supporting PSTs' planning with more careful anticipation of what could come up during the interactive work of teaching (e.g., Smith et al., 2008; Wilson & McChesney, 2018). Other efforts have focused on engaging novice teachers in analyzing students' work (e.g., Casey et al., 2018; Crespo, 2000; Kazemi & Franke, 2004; Lee et al., 2018; Silver & Suh, 2014). Although these efforts represent an improvement over the typical approaches for supporting novice planning (see John, 2006), we echo the sentiments of others—these approaches still leave too much of the learning of interactive aspects of teaching for PSTs to learn on their own.

Beyond competently analysing and interpreting a piece of written student work, a responsive teacher must be able to listen to and interpret a student's verbal contributions (Doerr, 2006; Fyhn & Berntsen, 2022). For these more interactive aspects of practice, scholars have explored the potential for engaging PSTs in approximations of practice with fuller representations of student-teacher and student-student interactions (e.g., rehearsals, Ghousseini, 2017; replays, Horn, 2010; simulations, Dieker et al., 2019; role-playing, Shaughnessy & Boerst, 2018; scripting, Zazkis & Zazkis, 2014; letter writing, Crespo, 2003; Greenwald, 2000; storyboarding, Herbst et al., 2019; animating, Earnest & Amador, 2017).

Amid the plethora of emerging new approaches for teacher education, Forzani (2014) examines ways that the growing number of so-called *practice-based teacher education* initiatives are a result of simply applying the *practice-based* label to previously-used approaches to teacher education. Distinct from those previous approaches, Forzani argues for the distinct value of practice-based approaches that center on supporting prospective teachers to gain core competencies through experiences approximating content-specific practices (leading a whole class discussion centered on a mathematical task). She notes, "There is no evidence that …large numbers of American teacher educators are adopting [that kind of] approach" (p. 366). These sorts of critiques (see also Zeichner, 2012) suggest a need for more careful consideration regarding how we assess the potential of those efforts who purportedly organize under the banner of "practice-based teacher education". Further, these critiques highlight the need to develop theoretical frameworks for describing the potential and kinds of interactions promoted within the growing approaches to approximation.

2: Gauging the potential of various forms of approximation used in teacher education

The use of approximations of practice has developed, in part, to respond to the need for PSTs to engage in repeated opportunities to practise interactive teaching prior to formal clinical placements (e.g., Bondurant & Amidon, 2021; Kavanoz & Yüksel, 2010; Kazemi et al., 2009; Kourieos, 2016). While the development of innovative forms of approximation has gained traction in recent years (e.g., Ayalon & Wilkie, 2021; Kavanugh et al., 2020), less has been done to draw distinctions between various forms of approximations in terms of their potential for supporting growth of prospective teachers' knowledge and practices for teaching. Among the various kinds of approximations listed there are some important differences worth clarifying. One difference that may prove meaningful for PST learning relates to the different kinds of repeated opportunities various approximations make available. One kind of repeated opportunity includes the engagement of novices in a set of skills/practices that are part of the regular or habitual things teachers do while in the act of teaching (Lesseig et al., 2016; Monson et al., 2020; Wieman & Webel, 2019; Webel et al., 2018). A second kind of repeated opportunity includes the expectation for novices to string those skills together into larger segments of interaction that more closely represent the work of teaching (see Janssen et al., 2014).

The development of competent novice teachers may benefit from having repeated opportunities of practising teaching both in terms of skill development and implementation of skills developed. For example, in a *standardised teaching simulation* (Shaughnessy & Boerst, 2018) a novice is asked to approximate the role of a teacher in the *practice of eliciting mathematical thinking* while another adult plays the role of a student with a particular profile. Where *rehearsals* (Lampert et al., 2013) provide PSTs with repeated opportunities to practise longer segments of teaching in which a novice approximates the role of a teacher carrying out an instructional activity in order to practise teaching content to a full class.

The various forms of approximation also differ in the nature of role-playing and the source of feedback. In the case of both the *standardised teaching simulation* and *rehearsals,* the novice plays the role of the teacher while the MTED plays a simulated student. In other kinds of approximation, such as *Lesson Plays* (Zazkis et al., 2009), the novice is asked to role play not only the actions of the teacher, but also the responses of the students. Between these two models, the source of feedback on practice differs. When the MTED plays the role of the student in a rehearsal, he/she provides feedback in two ways: direct and indirect feedback. Direct feedback is often provided by the MTED "interjecting feedback in a novice's teaching performance" (Lampert et al., 2013, p. 230). Indirect feedback is provided when the simulated student/class acts back in ways that represent "the intellectual and social range of actions that might be anticipated" (Lampert et al., 2013, p. 229). When the novice plays the role of the student, feedback comes from the very act of having scripted the part of the student. Some hypothesise this kind of role playing might help novices to learn to "think or talk like a student," which "might help [them] develop better models of students' conceptual schemes" (Zazkis et al., 2009, p. 45).

Finally, another key difference relates to formats (e.g., synchronous vs. asynchronous) and mediums of the approximations (e.g., enactments vs. narrations vs. storyboards). Some approximations (e.g., r*ehearsals,* as described by Lampert et al., 2013) require synchronous participation of the MTED—taking substantial instructional time, which may limit opportunities for PSTs to engage in an ongoing manner. That said, the synchronous format may provide a common experience for PSTs creating different learning opportunities than via an asynchronous format. Distinct from the delivery formats, the mediums of various approximations offer differing opportunities for regular practice and feedback (Sweeney et al., 2018). For example, the storyboard medium allows participants to reflect on dialog as it is generated and fashion revisions until satisfied. In this way, a storyboard medium may provide more immediate self-regulating feedback that novices can use to gain more autonomy in their own learning.

Some evidence that the medium may make a difference exists already. Chen (2012) conducted a study examining what storyboarding could afford to PSTs engaged in anticipating a planned lesson. In her analysis, she compared the anticipation of lessons by two groups of PSTs: one in which the PSTs provided verbal narratives of lesson anticipations, and another in which the PSTs anticipated their lessons using storyboards. Chen found that when storyboarded, lesson anticipation contained significantly more attention to critical aspects of the lesson enactment (e.g., students' conceptions and misconceptions were spelled out, potential interactions were sketched, task details were provided) than when PSTs simply narrated the lesson. Consistent with other research regarding the use of the storyboard medium with PSTs (Herbst et al., 2014; Rougée & Herbst, 2018), Chen's findings suggest storyboarding provides stimulus for anticipating more details than merely planning and discussing lessons. More research, however, is needed to explore the learning process afforded by using storyboards to simulate and rehearse teaching practice for PSTs.

3: The Story*Circles* Process

Story*Circles* engage teachers in approximations of practice that leverage the storyboard medium. The Story*Circles* process was originally designed to engage in-service teachers in anticipating collaboratively, with help from an online storyboarding tool (Lesson*Depict* hereon), how a particular lesson might unfold (Herbst & Milewski, 2018). The interaction allows participants to use their knowledge and experiences to share instructional moves they envision for each stage of the lesson as well as ways students might react to those moves. Collectively, the Story*Circles'* participants leverage the capabilities of Lesson*Depict* to visualise a lesson as it is being anticipated and consider the suggestions of individuals while offering alternative ideas. This gives participants an opportunity to: individually ***script*** instructional actions, collectively ***visualise*** and provide feedback regarding instructional choices, and collectively consider or ***argue*** about alternative options for the same instructional moment (see Figure 1). The group in Figure 1 is comprised of multiple participants and a facilitator. In this research, the PSTs were the participants and an MTED was the facilitator.

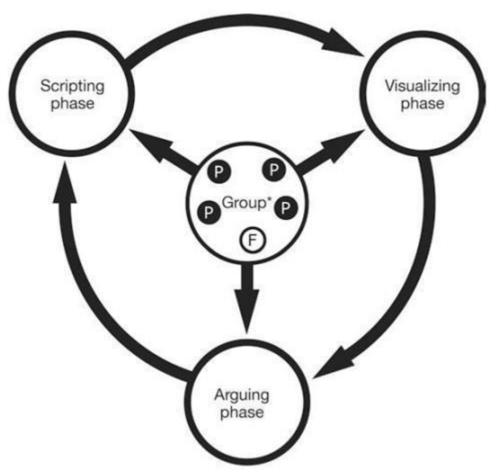


Figure 1. A representation of Story*Circles* where Ⓟ represents a participant and Ⓕ represents a facilitator (Herbst & Milewski, 2018).

At the beginning of a Story*Circles*, the group of participants are provided with the parameters of collectively producing a single representation of a lesson, in the form of a storyboard, of a particular instructional task for a particular instructional goal. With these parameters, participants begin scripting portions of the lesson that are then visualised using Lesson*Depict.* The drafted storyboards of the lesson anchor subsequent discussions about the lesson that occasion revisions of the storyboard, and the cycle continues until the group is satisfied. Since our aims for Story*Circles* include centering on and leveraging teachers' knowledge and experiences, a crucial design principle includes encouraging the facilitator to let the interactions between the teachers guide the direction of the group's work (see Herbst & Milewski, 2018). That is, the canonical role of a Story*Circles* facilitator departs from the typical one in which the facilitator guides the group's learning. Instead the role of a Story*Circles* facilitator is one of eliciting teachers' ideas, orienting participants to one another, highlighting places of disagreement, and helping the group move towards coalescence through consideration of alternative ideas and justifications.

Lesson*Depict* (https://www.lessondepict.org) provides the medium for the virtual representation of the participants' suggestions. Lesson*Depict* allows users to iteratively prototype cartoon-based representations of classroom stories using a customisable graphical language of nondescript cartoon characters (see Figure 2), which allows teachers and MTEDs to represent teaching interactions (Herbst et al., 2011). The graphics within Lesson*Depict* include classroom scenes (front, back, and side views of classrooms with a variety of furniture arrangements), classroom characters (students and teachers), dialog bubbles and supplies (books, papers, writing utensils, manipulatives, etc.).

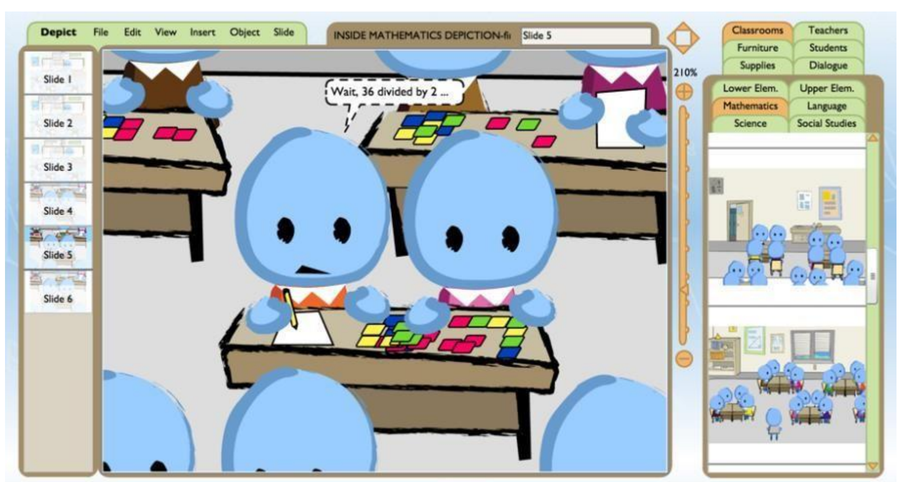


Figure 2. Screen capture of Lesson*Depict*, as it existed in Lesson*Sketch* (Herbst et al., 2013), used to generate representations of mathematics lessons.

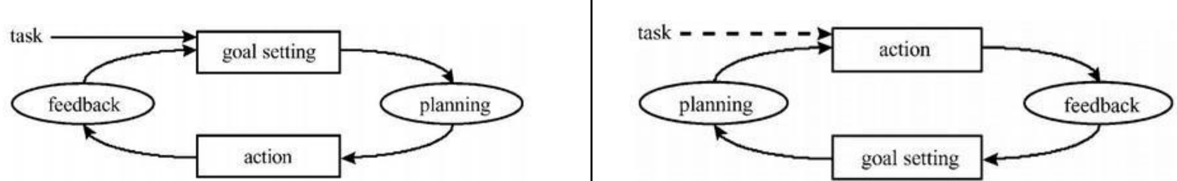
We suggest that the virtual representation of storyboards as embedded in the Story*Circles* process provides feedback to participants from which they might learn, both from the representation itself as well as from participants interacting with the same representation. Drawing on constructionist notions of learning, Herbst et al. (2014) argued that the material artefacts of storyboards provide opportunities for self-regulating feedback from the environment—like one might receive in microworld environments such as LOGO or Minecraft (e.g., Papert, 1980, 1993; Short, 2012; Spiliotopoulos et al., 2019). Building on that argument, we suggest the collaborative and public construction of storyboard artefacts embedded in the Story*Circles* process adds a second kind of feedback for participants—namely the sharing of knowledge amongst individuals (see also Tettegah, 2005). Weber (2000), who studied the organising features of workgroups, described the critical role of material representations for "mutually transferring [group member's] individual knowledge, expertise, and experience into a material form" and thereby making "materialized knowledge and expertise available for other group members" (p. 91). In this same way, the storyboards act as critical resources enabling teachers to specify their ideas with enough detail for others to see what was meant and, thereby, make that knowledge available for consideration and learning.

Prior work has demonstrated the potential of the Story*Circles* process for supporting in-service teacher professional growth and learning in the context of professional development (Brown et al., 2021; Herbst et al., 2020; Milewski et al., 2018, 2020). In that research, Story*Circles* was described as having the potential to benefit teachers' mathematical knowledge for teaching and practice as they consider the alternative actions proposed for the same moment as well as the justification provided for those actions. The implementation of the Story*Circles* process with a new population allows us to investigate the use of storyboards and animations as a vehicle for engaging PSTs in approximations of practice and potentially add to the work on innovative forms of approximation in the field of teacher education. The research reported in this paper builds on Grossman et al.'s (2009a) notion of approximation while also building on common instructional activities for approximating teaching by providing PSTs with repeated opportunities to learn in, from, and for practice.

4: A model for capturing two contrasting types of approximations: Goal-Directed and Exploratory Cycles

Emerging from our desire to understand the potential of Story*Circles* with PSTs, we sought out literature describing ways that physical and virtual tools mediate collective professional work. Organisational psychologists Fjeld et al. (2002) examined the use of an augmented reality system developed to enhance professional collaboration by allowing groups of professional architects and designers to "co-locat[e] around a table, to interact, by means of physical bricks, with models in a virtual three-dimensional setting" (p. 153). The researchers identified two contrasting types of action-regulation cycles (Figure 3):

1) ***goal-directed action cycles*** in which individuals work together to set goals before taking action; and
2) ***exploratory action cycles*** in which the work begins before a "specific goal is available for initial action" and "only after the receipt of feedback, which gives information on the means available, can a goal be generated" (Fjeld et al., 2002, p. 159).



Goal-directed action cycle | Exploratory action cycle

Figure 3. Two action cycles described by Fjeld et al. (2002)

Fjeld et al. (2002) report observing that individuals' collaborative use of physical and virtual tools enabled participants to move back and forth between these two types of cycles in ways that facilitated their progress. They describe how the exploratory action cycles have the virtue of unveiling hidden information about work that would otherwise take a great deal of mental calculation to see.

We see this way of working—with PSTs moving fluidly between goal-directed and exploratory action cycles—as having potential for accelerating PST learning about both strategic and tactical decisions teachers make in the design and implementation of lessons. Where goal-directed cycles align with decisions teachers make during preactive phases of teaching (e.g., determining the lesson goals and activities prior to teaching), exploratory cycles mirror the decisions that teachers make during the interactive phases of teaching.

As illustrated in Figure 4, PSTs' engagement in goal-directed action cycles (left), such as planning a lesson, can be linked with their engagement in exploratory action cycles (right) in ways that enable PSTs to explore how aspects of their plan might actually play out. We call this model the Dual Action Cycles of Approximations of Practice. We suggest that augmenting goal-directed cycles with exploratory action cycles could provide PSTs with opportunities to consider the more tactical decisions they often overlook while planning (e.g., anticipating students' mathematical contributions as well as the ways one could respond to those contributions). By simulating those more tactical actions, a PST makes his/her decisions available for feedback (both self-reflection and inspection by others) and such feedback can lead to crucial realisations about how particular decisions impact the elements of practice (e.g., how the selection of student work facilitates the larger goals of the lesson). Such realisations may suggest to PSTs the need to suspend the approximation of instruction (leaving the exploratory cycle) in order to reconsider their plan (returning to the goal-directed cycle). These reflections can also lead to realisations about elements of practice that are oftentimes only addressed after implementation (e.g., some responses to students might send unintended messages about what it means to do mathematics). This kind of realization may result in the PSTs taking several loops around the exploratory action cycle until they are satisfied with a particular segment of action. In this way, we see ways PSTs' work could oscillate between preactive and interactive kinds of work—with participants moving fluidly between the two cycles—and this way of working can provide PSTs with natural feedback loops.

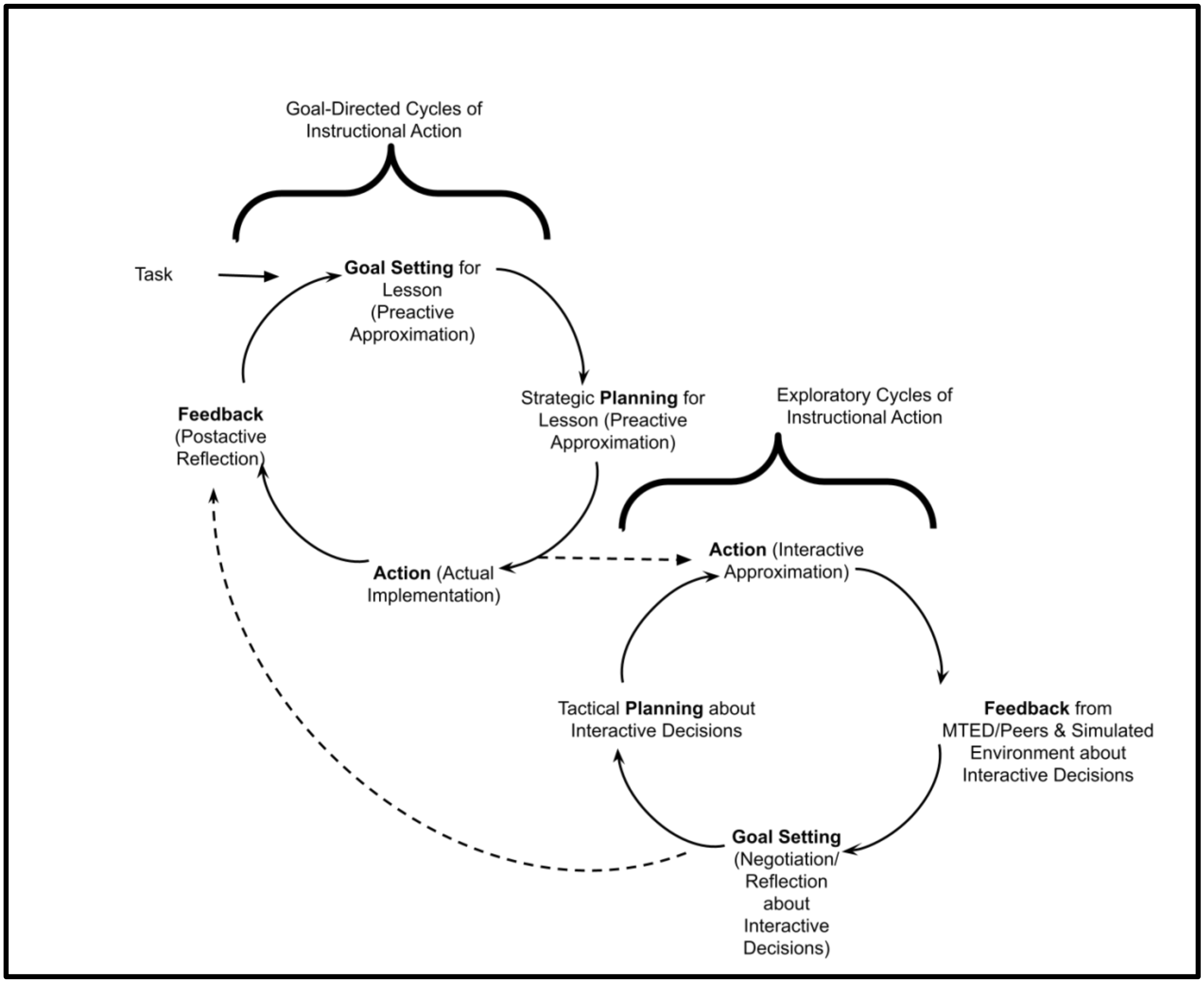


Figure 4. The Dual Action Cycles of Approximations of Practice.

To explore the potential of the ***Dual Action Cycles of Approximations of Practice***, we ask the following overarching research question:

How can goal-directed and exploratory action cycles be used to support PSTs in approximations of practices?

To illustrate this potential, we use a small body of empirical data—the interactions between two PSTs engaged in a single 150-minute Story*Circles*—to gauge the potential of Story*Circles*. We asked the following three sub-questions:

1. What kinds of activity can we expect of PSTs engaged in Story*Circles* and in what ways is that activity supported by the presence of the virtual space for visualising?

2. What aspects of the everyday work of teaching (if any) might PSTs have repeated opportunity to approximate by engaging in the collaborative storyboarding of a lesson?
3. How do the interactions in the Story*Circles* activity create repeated opportunities for PSTs to approximate practices from both the preactive and interactive phases of teaching?

5: Methods

5.1: Data Collection

In this paper, we focus on the interactions of two secondary mathematics PSTs, Daksha and Kathy, who engaged in a Story*Circles* interaction during their final semester of preparation before student teaching. These interactions took place outside of the students' formal coursework and spanned a total of 150 minutes. Both PSTs had very little experience teaching, each having only taught short lessons in their school placements. The participants were drawn from a cohort of four secondary mathematics PSTs. All four of the secondary mathematics PSTs in a local secondary TE program were invited to participate and Daksha and Kathy volunteered to do so. None of the research staff on the project was at the time an instructor in the students' teacher education program. The choice to conduct the session outside any official teacher education instruction is consistent with the exploratory nature of the project, as we were still learning about the potential of Story*Circles* for supporting novices in learning to teach.

Participants were given a mathematical task (Figure 5, drawn from Chapter 3 of Chazan, 2000)—involving the conversion between temperatures measured in Fahrenheit and Celsius scales—along with ten pieces of accompanying de-identified student work (previously collected by the second author from high school students; summarised in Table 1). Our choice to provide both the task and student work was deliberate in that it enabled PSTs to attend more fully to the practices engaged during the enactment of a lesson, rather than those from the preactive phases of teaching.

The freezing point is 32 degrees Fahrenheit or 0 degrees Celsius. Water boils at 212 degrees Fahrenheit or 100 degrees Celsius. I set the thermostat at home at 70 degrees Fahrenheit, what should I set it to if I had a Celsius thermostat?

Figure 5. The mathematical task we provided to PSTs.

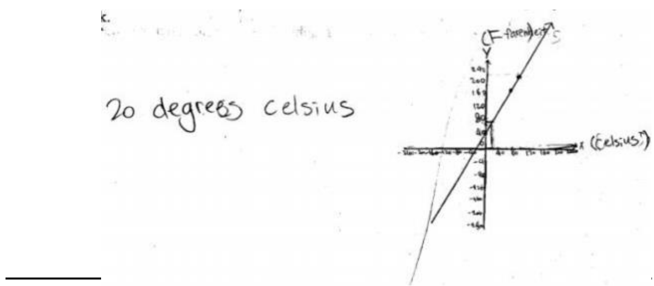
Table 1

Types of accompanying student work provided to PSTs

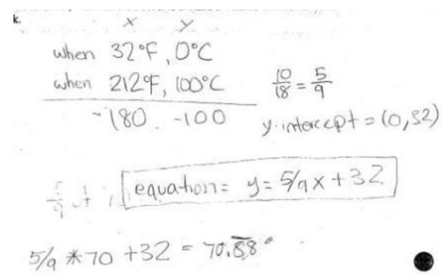
	Graph	Recalled formula	Equation	Proportion	Numerical method
Correct	1	1	2		
Incorrect	1		2	2	1

The accompanying student work included both correct and incorrect solutions as well as a variety of different strategies—featuring work from high school students who had used equations or graphs, as well as work from students who had attempted to treat the values as proportional. To focus on the more interactive phases of teaching, the facilitator asked the PSTs to discuss how such a lesson might unfold, given this task and associated student work. Further, the facilitator described to the PSTs that they would have the assistance of an experienced user of Lesson*Depict*—storyboarder hereon—to generate and display a storyboard of the lesson they anticipated. The storyboarder was present in order to remove any technological barriers for the participants' activity. After discussing, the PSTs selected three pieces of student work (Figure 6a-c) that were eventually associated with students in the storyboard—who were named by the PSTs based on the color of the vests shown on the students depicted (i.e., student shown wearing an orange vest was given the name Orange). One of those pieces was discarded and replaced with another piece of work (Figure 6d).

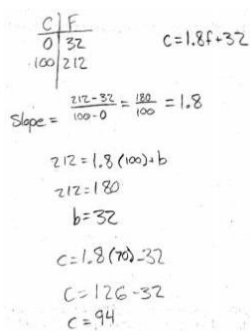
A. Approximately correct work using a graphical approach (Attributed by PSTs to depicted student with Orange vest)



B. Incorrect work using an equation (Attributed by PSTs to depicted student with Pink vest)



C. Incorrect work using an equation which was eventually discarded by PSTs (Attributed by PSTs to depicted student with Blue vest)



D. Incorrect work using proportion which was eventually selected to replace work shown in Figure 6C (Attributed by PSTs to depicted student with Yellow vest)

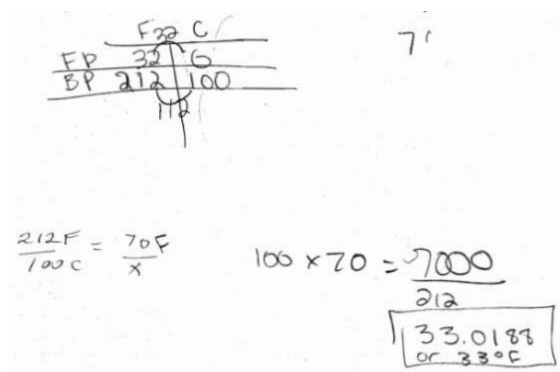


Figure 6. Four of the ten pieces of student work that Daksha and Kathy selected for the whole class discussion.

We gathered data through two main sources, a video recording of the Story*Circles* interaction and the storyboard created. The conversations between Daksha and Kelly as well as their interactions with Lesson*Depict* were video-recorded and transcribed for purposes of analysis.

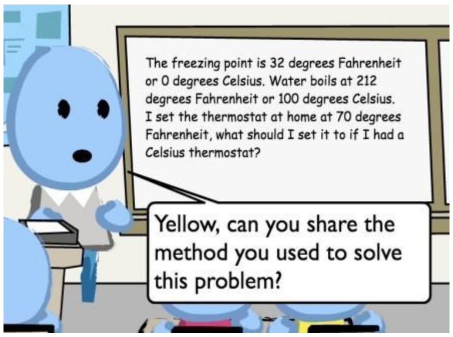
5.2: Data Analysis

To understand the kinds of activities one can expect of PSTs engaged in Story*Circles* and ways that the virtual space for visualising supported that activity (sub-question 1), we began by constructing a transcript of the PSTs interactions and then segmented that transcript. The evidence we used to identify the beginning and ends of segments included verbal and nonverbal cues indicative of a change in PSTs' focus. Sometimes participants indicated they were ready to move to another portion of the interaction with verbal cues (Jordan & Henderson, 1995)—after drafting a dialog bubble, saying things like "I think it's fine" (Kathy, 1:31:34) or "Okay, what comes next?" (Daksha, 1:31:42). On other occasions, participants provided nonverbal cues such as preparatory activities, disengagement, and rearrangement of artefacts (Jordan & Henderson, 1995)—moving from scripting the whole class discussion around the work of one student to scripting the whole class discussion around the work of a different student. Last, participants indicated shifts by transitioning to new activity structures—moving from doing a mathematical task themselves to discussing samples of students' work.

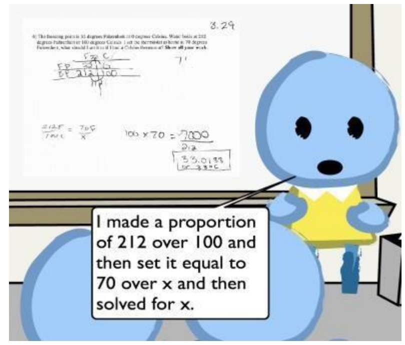
We constructed a preliminary interaction outline that included segments in which participants interacted primarily with the storyboard evidenced by their referencing, gesturing, or gazing towards the storyboard. We also noted whether the PSTs or facilitator initiated the phases of the interaction to gain a better understanding about which segments of the Story*Circles* interaction PSTs were able to direct and sequence themselves. We conjectured that those segments in which PSTs engaged primarily with the storyboard would correspond with the segments in which they were able to direct and sequence their own engagement in approximations of various instructional practices. Finally, we distinguished those segments according to whether the kind of work PSTs were approximating was preactive, interactive, or postactive.

To understand the kinds of work that PSTs had the opportunity to engage in within Story*Circles (*sub-question 2) and the ways that the Story*Circles* processes supported those opportunities (sub-question 3)*,* we conducted an analysis of the dialog from the final storyboard artefact produced by the PSTs. In particular, we coded each speech bubble according to one of four types of moves: ***soliciting*** mathematical thinking, ***contributing*** mathematical thinking, ***reacting*** to another's mathematical contribution, and ***structuring*** behaviours or activities (see Figure 7). We select these categories because they have been repeatedly used by researchers as a descriptive model of the language of classrooms (e.g., Bellack et al., 1966; Fernández, 2007; Piburn & Middleton, 1998; Sinclair & Coulthard, 1975).

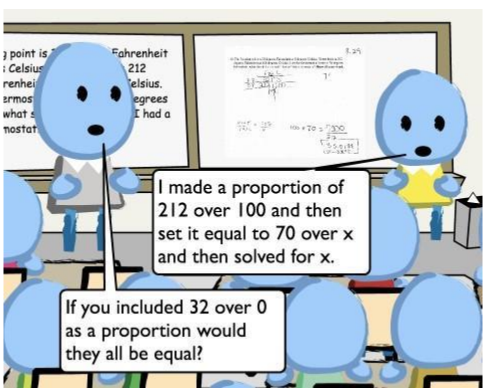
Dialog from the Storyboard & Type of Discursive Move



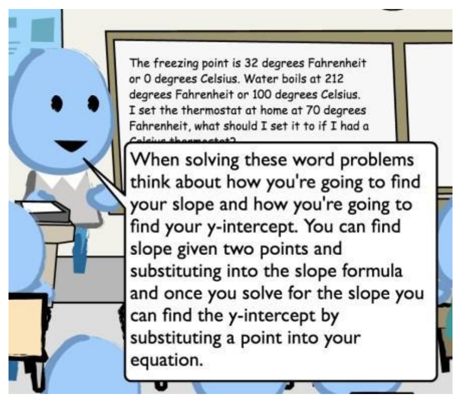
Teacher ***Soliciting***



Student ***Contributing***



Teacher ***Reacting***



Teacher ***Structuring***

Figure 7. Examples of the four types of dialog bubbles from the storyboard

Next, to have a sense of how long the PSTs dwelt on the construction of particular elements of the storyboard, we tracked how the PSTs interacted with each speech bubble—tracking the number of revisions and evaluative comments made. To do this we located places in the transcript in which the PSTs interacted with one another to construct each dialog bubble, tracing the initial call for a bubble, its associated dialog and subsequent revisions. For example, a PST might offer an initial call for a dialog bubble. After seeing their suggestion represented in a storyboard, PSTs sometimes provided some kind of indication that they were displeased with their first attempt and such reflection spurred some kind of revision. Sometimes the PSTs offered four or more revisions of the same bubble. After tracking the development of each dialog bubble, we noted the total number of revisions suggested by the PSTs in order to look for trends amongst the different types of speech bubbles according to the speaker and type of discourse move.

In addition to identifying the number of revisions PSTs scripted, we also inspected the PSTs' interaction with particular dialog bubbles for evidence of PSTs' appraisal of their own efforts. We used the appraisal system of language (Martin & White, 2007) to code comments the PSTs made in reference to each version of a dialog bubble—tracking those comments made about the various revisions to each dialog bubble which contained one or more markers of affect (e.g., the PST says "I like what we have written here"), judgement, (e.g., the PST says "That was inappropriate for the teacher/student to say that") or appreciation (e.g., the PST says "That dialog bubble is vague"). These comments took the form of evaluation of the classroom dialog and helped us to understand the ways in which participants were seeing improvement across the versions.

6: Findings

We organise our findings into four sections. First, we describe the activity phases PSTs engaged in across the *StoryCircles* interaction to provide the reader with a bird's eye view of the interaction—sharing findings regarding the first research sub-question. Across the second and third sections, we address research sub-questions two and three by taking a more thorough look across the Story*Circles* interaction. We close with some reflection across the three preceding sections—discussing Story*Circles* more specifically and the model more generally in order to consider the potential of augmenting preactive approximations with iterative approximations of the interactive work of teaching.

6.1: Using StoryCircles to support reflection on practice and self-directed learning

In this section, we describe how the 150-minute Story*Circle* interaction could be parsed into phases—focusing on how the storyboard served as a source of formative feedback for the PSTs. Outside of the first five phases of the Story*Circles*—in which the facilitator initiated the interaction—the PSTs initiated the remaining 14 of the 15 phases of work. The only other facilitator-initiated phase came with the bid for a final review of the storyboard (Table 2).

Table 2

Phases of Interaction

Time (min)	Phase Initiator	Description of Interactions	Action Cycle	Story*Circle* Phase
4	Facilitator	Completing the mathematical task		
13	Facilitator	Understanding student work		
2	Facilitator	Understanding the work we have asked them to do		
6	PSTs	Selecting a lesson goal	Goal-directed	
5	Facilitator	*Understanding the role of the storyboarder		
9	PSTs	Selecting & Sequencing Pink's, Blue's, and Orange's work	Goal-directed	
16	PSTs	*Scripting the launch & eliciting student work	Exploratory	Scripting & Visualising
31	PSTs	*Scripting the whole class discussion of Pink's work	Exploratory	Scripting & Visualising
<1	PSTs	Discarding Blue's work	Goal-directed	Arguing
8	PSTs	*Scripting the whole class discussion of Orange's work	Exploratory	Scripting & Visualising

3	PSTs	Selecting and sequencing Yellow's work	Goal-directed	Arguing
12	PSTs	*Scripting the whole class discussion of Yellow's work	Exploratory	Scripting & Visualising
3	PSTs	*Identifying need for transitions between students' presentations	Exploratory	Visualising & Arguing
5	PSTs	*Scripting a conclusion based on lesson goal	Exploratory	Scripting & Visualising
12	Facilitator	*Determining the goal was not met by reading the whole storyboard	Goal-directed	Visualising
4	PSTs	*Revising the lesson goal by scripting a concluding statement to match the lesson	Exploratory	Arguing & Scripting

*Indicates places in which the PSTs' interaction was mediated by the storyboard

The PST-directed work included the preactive, interactive, and postactive aspects of teaching. The PSTs dwelt as long as they wanted on particular segments of the lesson, sometimes electing to return and modify segments of the lesson they had already moved on from. For example, the transitions between the students' presentations were not scripted until after all three whole class discussions about the student work were complete. After scripting the discussion of Yellow's work, Daksha noted that Pink's work should come next but seemed surprised when the storyboarder moved to the next frame, saying "Wait … why? Didn't we finish that?" (1:56:59). At that point, Kathy noted the need for a transition between the two students' work as well as the need for a transition between Pink's and Orange's work earlier in the storyboard. This is not surprising given that novice teachers often forget to plan for transitions (Chen, 2012; Hogan et al., 2003). Crucially, the PSTs were able to ultimately attend to the need for transitions without facilitator intervention. But it was only after moving across the storyboard frames that represented one student followed by a frame representing another student that the PSTs noticed the need for a transition. This suggests the visual feedback PSTs receive while reviewing the storyboard artefact may be a critical component of Story*Circles* for supporting PSTs to reflect on their own instructional moves (consistent with findings by Chen, 2012).

Similarly, the PSTs dwelt as long as they needed to perfect smaller elements of their choosing within particular segments of the lessons. For example, some dialog bubbles received up to 8 revisions from the PSTs, while others received none (n = 41 dialog bubbles, mean = 1.17 revisions per bubble, median = 1 revision per bubble, SD = 1.63). Likewise, some bubbles were subjected to up to 6 evaluative comments while others received none (n = 41 dialog bubbles, mean = 1.22 evaluative comments per bubble, median = 0, SD = 1.65). This suggests that through reflection on the storyboard, Story*Circles* can provide context for PSTs to have the opportunity to gain more autonomy in their learning by deciding about which parts of instructional practice are most troubling for them and choosing to elect time working on refining those aspects. Of course, a MTED may at times wish to have more of a say about which aspects PSTs need to attend to. The Story*Circles* activity does not preclude MTEDs from intervening in that way, but it does provide MTEDs with a choice about when and how to do that, while having some assurance that PSTs will, in the meantime, be working on some aspects of practice they themselves identify as needing attention.

6.2: Using StoryCircles to support approximation of preactive phases of teaching

Taking the whole interaction as the unit of analysis, we see the PSTs were engaged in what Fjeld et al. (2002) referred to as goal-directed action cycles. After completing the mathematical task for themselves and reviewing the student work, the PSTs agreed that the goal of the lesson was for students to "use these two points to figure out what [their] slope is and what [their] *b* [y-intercept] is, and using multiple methods that [they] can find to get to that answer" (Daksha, 00:42:39). After agreeing on the goal of the lesson, the PSTs selected three pieces of work to feature in the whole class discussion (Orange, Pink, and Blue shown in Figure 6) and then turned their attention to scripting the lesson—receiving feedback on their choices by viewing the storyboard. They sometimes used this feedback to immediately adjust their actions in light of their goals. For example, after they had scripted the discussion of Pink's work, Daksha looked at

Blue's work and said, "I don't think we need to do that one anymore" (1:31:53). Kathy agreed that Blue's work would no longer be useful since they had already "talked about the slope and the y-intercept in the last problem [the discussion of Pink's work]" (1:32:09). In this case, the PSTs used the feedback from the scripting of Pink's work to revisit the goal of the lesson and revise original choices regarding student work—discarding Blue's work.

In another instance, the feedback about the goal was less immediate—with PSTs deciding to adjust the goal of the lesson in light of actions they had chosen over the course of the Story*Circles* interaction. Specifically, the PSTs had originally selected particular pieces of student work to highlight that the problem could be solved using multiple methods. However, the PSTs drifted from this goal as they engaged in Story*Circles* and only returned to it when they were crafting the concluding statement for the teacher. The PSTs only crafted the concluding statement for the teacher after they engaged in a final read through of the storyboard from beginning to end. Kathy started by suggesting the teacher say, "Now you've seen methods that could be used to solve this type of problem …" (02:00:47), which was a concluding statement aligned with the goal the two had agreed on for the lesson. Daksha remarked "I mean, I feel like we only really used one way they can actually solve the problem. So maybe just saying, 'When solving these word problems, think about how you're going to find your slope and how you're going to find your y-intercept'" (02:01:00). Reflecting on the frames of the storyboard, Daksha realised that the lesson did not quite add up to the summary statement (or original goal) as stated by Kathy and rather than adjust the earlier actions, she suggested revising the summary statement. Because the revision to the goal did not come from the PSTs until after they had reviewed the storyboard, we suggest that it is possible the storyboard played a critical role in the PSTs' choice to adjust the goal.

6.3: Using StoryCircles to support approximation of interactive phases of teaching

Taking the phases of activity as the unit of analysis, we observe PSTs' activity aligning with exploratory cycles. We illustrate this with a closer inspection of a single phase of interaction, in which the PSTs alternated between *scripting*, *visualising*, and *arguing* in order to script the elements of whole class discussion of Pink's work. The PSTs began by scripting the whole class discussion of Pink's work, electing to have Pink present her work on the board.

While looking at Pink's work on the board, the PSTs noticed Pink had formed a conversion equation, taking Fahrenheit as the independent variable, indicated by an erroneously recorded y-intercept of (0, 32), which placed 0 degrees Fahrenheit equivalent to 32 degrees centigrade (see Figure 8a, 8b, and 8c).

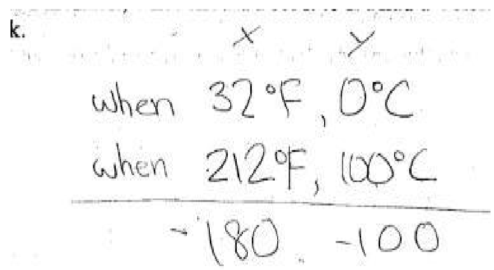


Figure 8a. Table of value Pink recorded from the problem

Figure 8b. y-intercept erroneously recorded by Pink

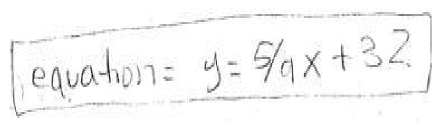
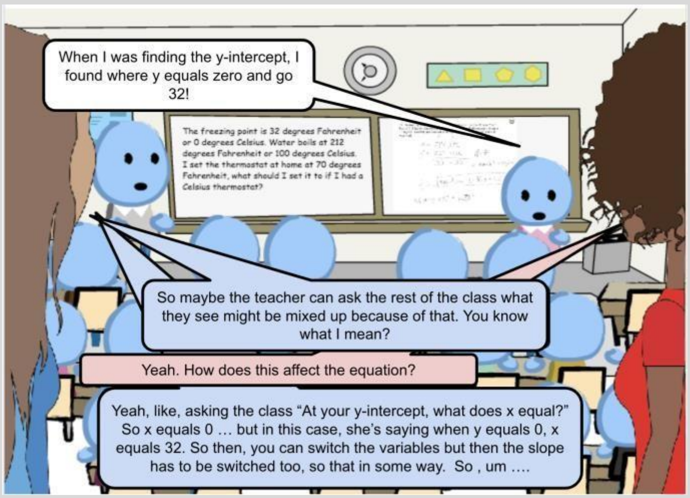


Figure 8c. Equation where Pink utilised incorrect y-intercept

After discussing Pink's error, Daksha scripted a teacher dialog bubble with, "maybe the teacher can ask the rest of the class what they see might be mixed up because of that" (1:05:43). After viewing her way of responding to the depicted student with, "What might be mixed up?", Daksha criticised her own contribution saying, "That sounds like a very vague question" (1:07:11) and revised the teacher bubble. To formulate this response, the PSTs iterated three cycles of *script, visualise,* and *argue* before settling on a final version. This pattern in the interaction cycle between the two PSTs is illustrated in Figure 9. To construct this illustration, we coordinated the revisions made to a single storyboard frame with the corresponding transcript from the PSTs—overlaying the verbal interaction (represented with colored bubbles) as it was produced by Daksha and Kathy (represented with the left and right commentators respectively) as happening in tandem with each revision to the storyboard.

<table>
<tr><th>Scripting</th><th>Visualise/Argue</th></tr>
<tr><td>


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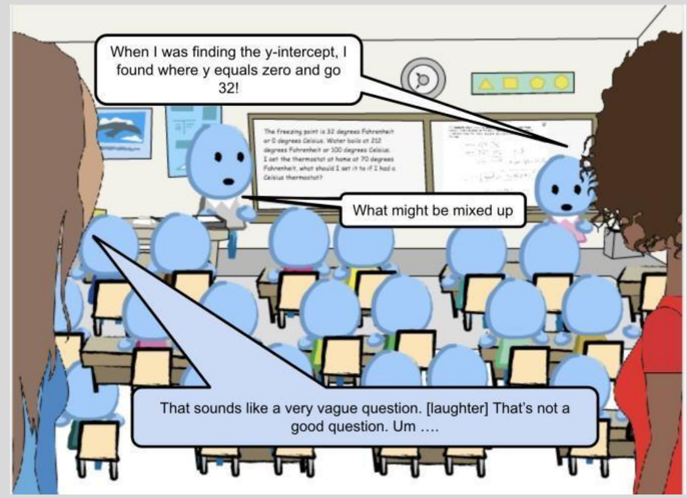

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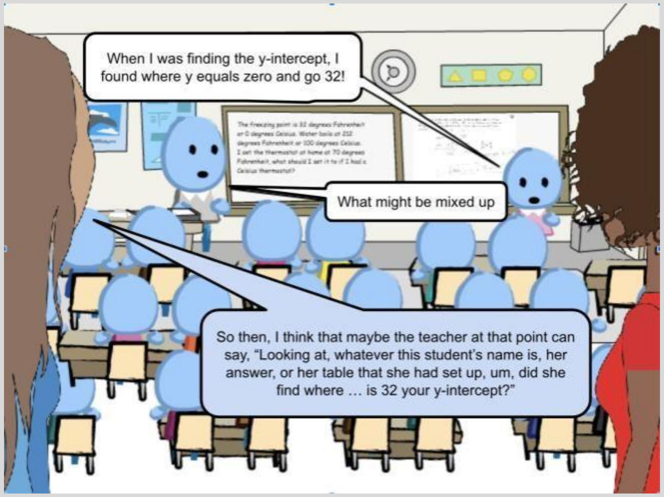
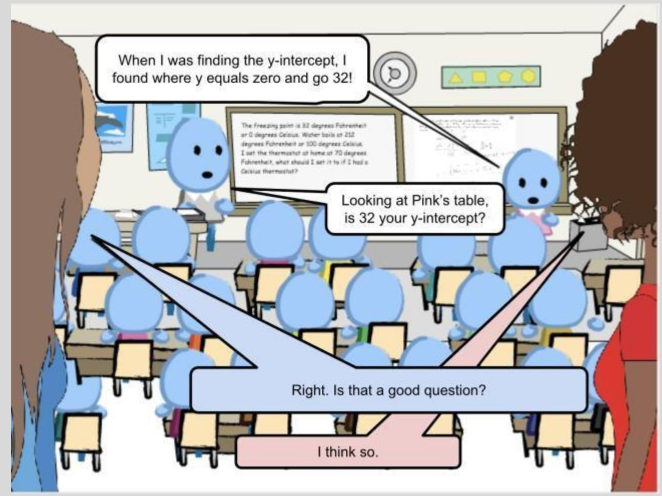
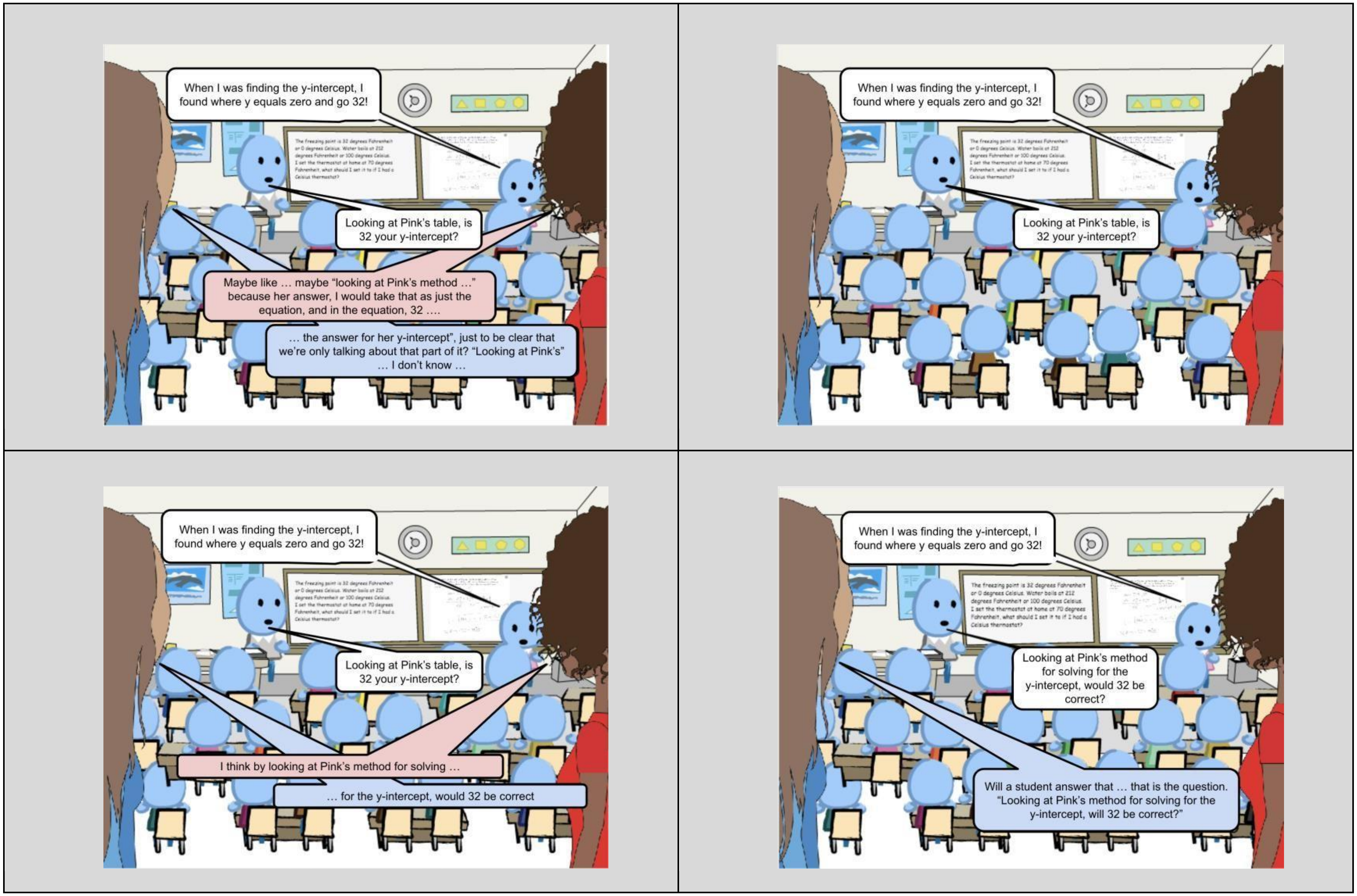
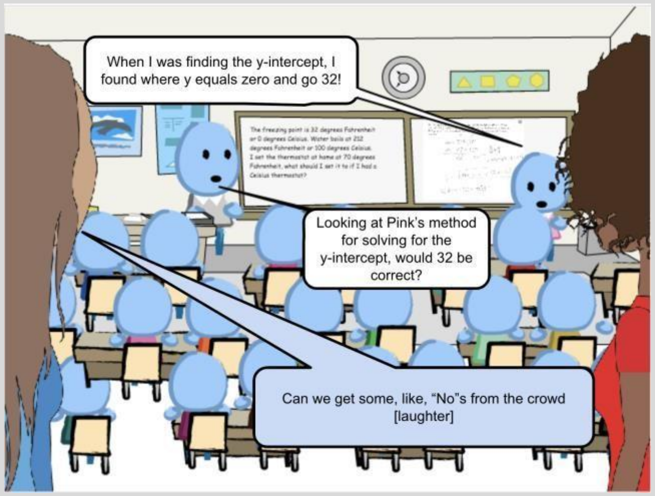


Scripting



Visualise/Argue


When I was finding the y-intercept, I found where y equals zero and go 32!
The freezing point is 32 degrees Fahrenheit or 0 degrees Celsius. Water boils at 212 degrees Fahrenheit or 100 degrees Celsius. I set the thermostat at home at 70 degrees Fahrenheit, what should I set it to if I had a Celsius thermostat?
Looking at Pink's table, is 32 your y-intercept?
Maybe like … maybe "looking at Pink's method …" because her answer, I would take that as just the equation, and in the equation, 32 ….
… the answer for her y-intercept", just to be clear that we're only talking about that part of it? "Looking at Pink's" … I don't know …
When I was finding the y-intercept, I found where y equals zero and go 32!
Looking at Pink's table, is 32 your y-intercept?
When I was finding the y-intercept, I found where y equals zero and go 32!
Looking at Pink's table, is 32 your y-intercept?
I think by looking at Pink's method for solving …
… for the y-intercept, would 32 be correct
When I was finding the y-intercept, I found where y equals zero and go 32!
Looking at Pink's method for solving for the y-intercept, would 32 be correct?
Will a student answer that … that is the question. "Looking at Pink's method for solving for the y-intercept, will 32 be correct?"

<table>
<tr><th>Scripting</th><th>Visualise/Argue</th></tr>
<tr><td>


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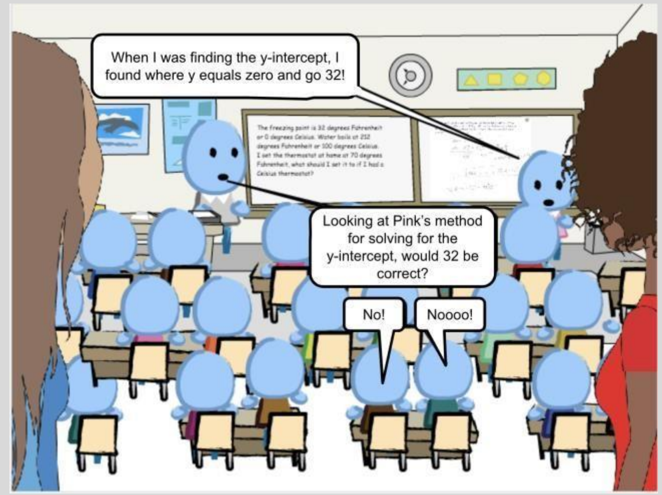

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</table>

Figure 9. Transcript excerpts overlaid a single frame of a storyboard PSTs generated—illustrating interaction cycle of script, visualise, argue

The action cycles proposed by Fjeld et al. (2002) helps make sense of the PSTs' interactions within Story*Circles*. Specifically, we see parallels between the activity cycles of Story*Circles* and the analytic categories provided by Fjeld et al. (Figure 10).

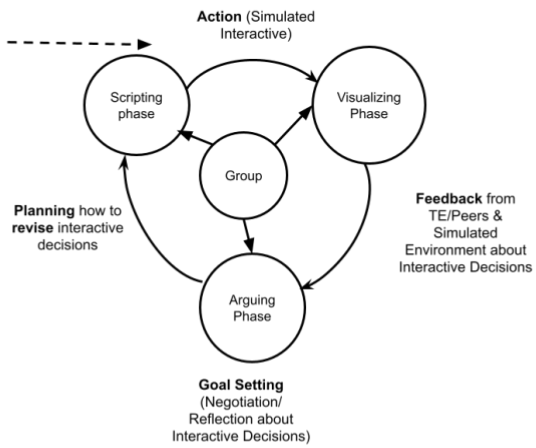	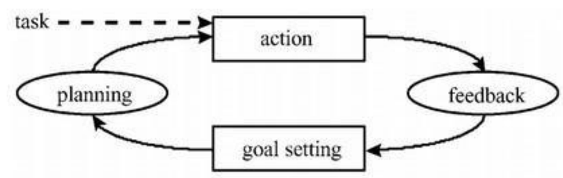
Story*Circles* exploratory action cycles	Fjeld et al.'s (2002) exploratory action cycle

Figure 10. StoryCircles exploratory cycles compared with Fjeld et al.'s (2002) exploratory cycles

The PSTs first *scripted* dialog for speech bubbles*;* once those actions were *visualised* in the form of a storyboard, they received *feedback* on that action; and that feedback elicited the PSTs to establish *goals* for the particular speech bubble by *arguing* for competing alternatives, and finally the PSTs *planned* for adjusted actions by suggesting *revisions*. This cycle of scripting, visualising, feedback, and arguing from the Story*Circles* process and seen across the PSTs' interactional data mapped quite naturally to the analytic cycles reported by Fjeld et al. (2002). In every case, this pattern emerged in the context of revising the dialog for the speech bubbles. It is sensible for the exploratory action cycle to emerge as the PSTs engage in the work of scripting dialog for frames. While the PSTs agreed early on regarding the lesson goal, there was no discussion about how that goal was to be carried out in specific moments. The storyboard frames provided PSTs with the opportunity to negotiate how the goal would be accomplished in moment-by-moment interactions. PSTs scripting and revision of dialog is likened to the sort of interactive work of actual teaching—although it occurs at a much slower pace than that of actual classroom exchanges—providing multiple opportunities for PSTs to engage in iterative cycles of improvement of interactive work.

Across the 150-minute interaction, the PSTs generated 41 dialog bubbles. Of those, PSTs gave slightly more attention to developing teacher turns; with the 26 teacher dialog turns receiving a total of 17 revisions and 14 evaluative comments, while the 15 student turns received only 7 revisions and 5 evaluative comments. Of the 26 teacher turns, the PSTs exerted slightly more effort perfecting those turns in which the teacher was responding to students' contributions—with the 12 responding turns receiving a total of 9 revisions and 9 evaluative comments compared with the remaining 14 teacher turns receiving 9 revisions and 5 evaluative comments. Overall, Story*Circles* provided context in which PST could rehearse and revise several core practices including:

eliciting students' mathematical contributions,

anticipating how students would express those ideas, and

responding to those mathematical contributions.

Further, the PSTs' appraisals of these revisions changed from negative to positive as they moved across these cycles—suggesting their ability to spontaneously reflect on their responses in ways that contributed to their perception of increased quality.

6.4: Potential of StoryCircles to support approximation of multiple phases of teaching

Prior to closing, we share what we have learned regarding the potential of the Story*Circles* process in providing PSTs with opportunities to move beyond more typical planning activities to engage in iterative approximations of the interactive work of teaching. To illustrate, we take a look again at the Dual Action Cycles model. This time, however, we incorporate the Story*Circles* process (Figure 11). Comparing this adapted Dual Action Cycles model with the data outlined in the above sections, we can see Daksha and Kathy's path through the approximation of the preactive, interactive, and postactive phases of work was quite circuitous.

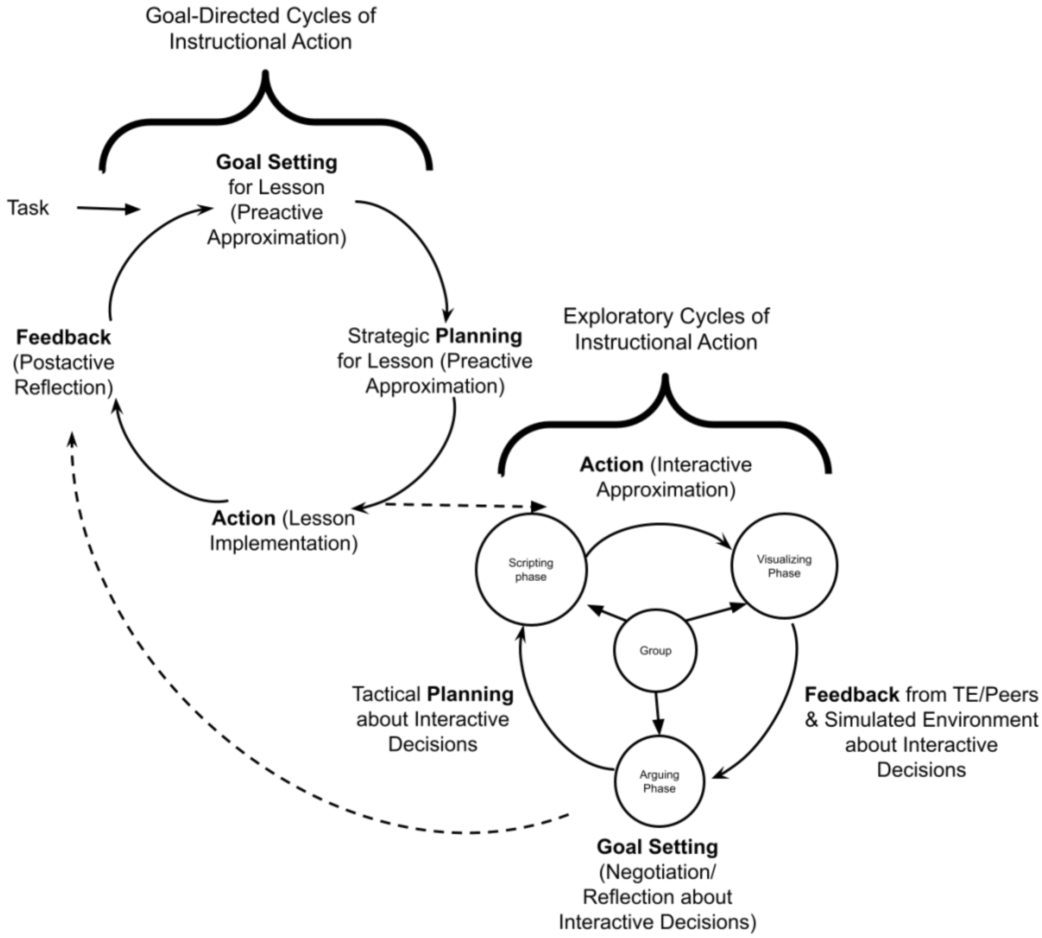

Figure 11. Dual Action Cycles of Approximations of Practice adapted for assessing Story*Circles*

The pair began within the goal-directed activity cycle—negotiating on the goals of the lesson and selecting and sequencing types of student work to align with that goal. Next, the two transitioned into the exploratory action cycle using the Story*Circles* phases—scripting, visualising, arguing about, and revising the launch and whole class discussion of Pink's solution. The two passed through these phases several times (taking several trips around the right-most circle) before moving on to the next phase of the lesson. After scripting Pink's work, the pair realised the second piece of work they had selected during the planning phase (Blue's) was too similar. In this way, the pairs' activity in the exploratory action cycle informed their work in the goal directed action cycle, and we surmise this led them to return to the left-most circle to adjust their original plan. With the decision to discard Blue's work behind them, the pair transitioned back to the exploratory action cycle to script Orange's work—again taking several loops around this cycle to perfect the interaction there. With the discussion of Orange's work storyboarded, the two PSTs transitioned back into the goal-directed action cycle to consider whether they needed another piece of student work with Kathy asking "Should we do one about proportions? Because I have two students who do that." (1:40:51). The pair used this break in the exploratory action cycle to select and sequence Yellow's work to come prior to both Pink's and Orange's—not wanting an incorrect solution to come last for fear it would embarrass the student.

Transitioning back to the exploratory cycles, the pair scripted the whole class discussion of Yellow's work, again taking several loops around the circles. Once done with Yellow's presentation, the two noticed the need to script the teacher transitions between student's presentations. Next, the pair scripted a conclusion for the lesson based on the goal they had originally agreed on, with Kathy scripting "Now you've seen methods that could be used to solve this type of problem and how there are methods that aren't the best way to determine the answer." (2:00:47). However, once that script was visualised, Daksha's reflection helped the pair realise they did not actually meet that goal—sending the two of them back to the goal-directed action cycle to decide on what goal they actually could claim having accomplished given the choices they had made in the lesson. After some deliberation and review of the entire storyboard, the pair transitioned one final time to the exploratory action cycle to take a few attempts at adjusting the concluding statement to something more specific to what was actually done by the class.

7: Discussion

We consider here our overarching research question regarding the potential of the Dual Action Cycles of Approximations of Practice—such as Story*Circles*—for supporting PSTs' engagement with various kinds of practices. First, the parsing of the goal-directed and exploratory action cycles in the model helps us to see the different kinds of activities that Story*Circles* afforded to PSTs opportunities to practise. By focusing on those portions of the Story*Circles* interaction in which the PSTs' activities aligned with goal-directed cycles, we notice PSTs were engaged in the approximation of the preactive aspects of teaching (e.g., completing the mathematics task for themselves, naming the mathematical goal). By focusing on those portions of the Story*Circles* interaction in which the PSTs' activities aligned with the exploratory action cycle, we see PSTs' actions tended to take up approximations of the interactive portions of practice (e.g., crafting dialog for the teacher to respond to a student's contribution). In these cycles, we notice that PSTs critiqued their own script once they saw it realised in the storyboard and took advantage of the medium to craft multiple revisions—all the while collectively negotiating the purposes for each speech bubble and using those purposes to craft further refinements.

In addition to the two distinct cycles, the adapted Dual Action Cycles model, helps us to understand how PST's engagement in Story*Circles* can weave back and forth between these two activity cycles. For example, after collectively establishing the lesson goals for the lesson, PSTs found ways to engage further with those goals by either: (1) accommodating those objectives by adjusting their actions (e.g., discarding Blue's work after reflecting back on the goal) or (2) adjusting those objectives to accommodate their previously taken actions (e.g., adjusting the lesson goal after visualising the lesson constructed). Note that these moments of realisation came as interruptions to the PSTs' work in the exploratory action cycles. For example, PSTs' decision to discard Blue's work came just after they were working out the details of what Blue would say at the board after Pink had already presented her work. Like the moments when pre-school children (e.g., in the middle of a playing house session), step out of character to negotiate expectations regarding the rules of the imaginary world they are co-creating (see Sanders & Harper, 1976; Meyers & Berk, 2014), the PSTs paused their simulated activity (e.g., developing the storyboard) to reflect and regulate their production of the storyboard according to the goals of the lesson they had set for themselves. Crucially, the Dual Action Cycles model was able to track such shifts in activity cycles as a potential support for PSTs' learning about the need to make an on-the-fly adjustment—an aspect of novice practice that has been shown difficult to cultivate (Taheri, 1982). Further, we would posit that the ways in which different approximations make this kind of moment (in which PSTs can pause and reflect on the goals of the lesson) available to PSTs may make a substantial difference in PSTs' opportunities to learn within such approximations.

The ability for the Dual Action Cycles model to track participants' actions within and across these two cycles facilitates thinking analytically about what might be important sources of feedback for PSTs within a particular kind of approximation. For example, the model suggests to us that the moments in which PSTs halt their exploration and reflect on their goals might be worth inspecting more closely. The realisation of the overlap between students' work came after

PSTs' use of the storyboarding tool to script Pink's work. Similarly, the realisation that they forgot transitions came just after the PSTs moved from one storyboard frame to another. Likewise, all evaluative comments and revisions PSTs made to dialog came after visualising it in the storyboard frame. These suggest ways that the storyboard medium serves as a kind of critical feedback for PSTs to redirect their own actions without facilitator intervention.

While the conclusions drawn here are limited, due to our small sample size, we note that the Dual Action Cycles model was useful for us in that it has helped us make observations about data collected from Story*Circles*, such as those we have shared here. Beyond its usefulness for gauging the potential of Story*Circles*, we posit that the Dual Action Cycles could be useful in gauging the potential of other approximations of practice. We acknowledge that as presented thus far, the model favours approximations related to the instructional practices entailed in the planning and teaching of a lesson. This is a product of our interest in assessing the potential of the Story*Circles* process in particular. We think with some small adaptations (see Figure 12), the Dual Action Cycle Model could be used with a wide variety of approximations— including those approximations of practice outside of classroom teaching, such as learning to facilitate parent-teacher conferences (e.g., Walker & Dotger, 2012; Khasnabis et al., 2018).

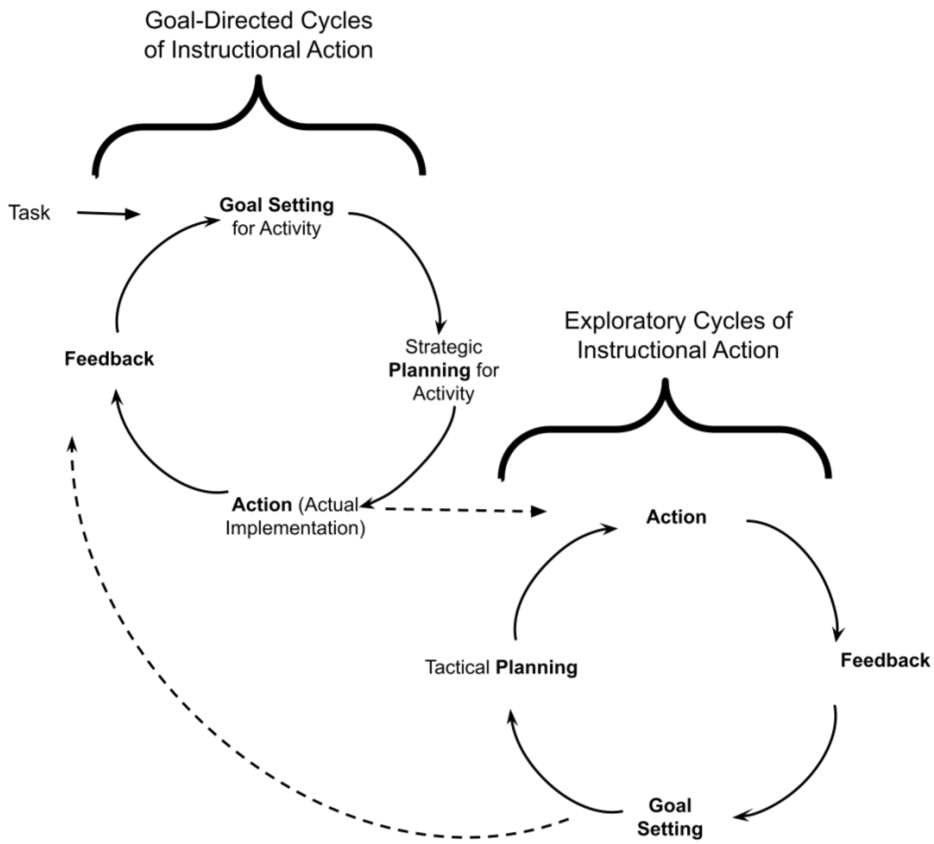

Figure 12. Dual Action Cycles of Approximations of Practice adapted for gauging the potential of an approximation of non-instructional practices

8: Conclusions

The structure of the Dual Action Cycles of Approximations of Practice has significant implications for those interested in developing, or gauging the potential of, innovative forms of approximation for teacher education. Teaching is a complex profession with much for PSTs to learn, and the amount of time devoted to learning practices in teacher education programmes is limited. Teacher educators have to make choices as they cannot afford to take on all forms of innovation with the limited time and resources they have in teacher education programmes (Sweeney et al., 2018). For these reasons, it is critical we develop methodological models for gauging the potential of the various forms of approximation, in order to gain a clearer understanding of the potential of each.

The Dual Action Cycles model presented in this paper helps to illuminate two potentials of the Story*Circles* process. First, we have illustrated the potential of Story*Circles* to facilitate more opportunities for PSTs to approximate practice because it allows PSTs to author aspects of practice in non-face-to-face asynchronous settings outside of course time. Second, we have illustrated the potential of Story*Circles* for providing formative feedback during the PSTs' planning processes. While there are other mathematics educators doing similar work in this area, (see de Araujo et al., 2015; Kalinec-Craig et al., 2021; Crespo et al., 2011; Earnest & Amador, 2017; Zazkis et al., 2009), there is something added to such work with the addition of easily-prototyped storyboards as a means for providing PSTs with formative feedback (Kalinec-Craig et al., 2021; Lee et al., 2018; Webel & Conner, 2017; Walkoe & Levin, 2018). We see evidence of this by looking for practices engaged by the two PSTs and the formative feedback they received from viewing the storyboard, as with the transition to and the formation of a teacher's response to student thinking. Our preliminary use of this Dual Action Cycles model in this research suggests to us that it is worth exploring further the potential of Story*Circles* to provide PSTs with a setting of reduced complexity to have regular opportunities to approximate and receive formative feedback on the instructional practices involved with the unfolding of a lesson.

Drawing on our use of Story*Circles* with inservice teachers, we anticipate one important affordance for using the storyboard medium is the opportunity it creates for MTEDs to indirectly introduce certain kinds of contingencies into PSTs work in order that they can receive opportunities to practice handling such contingencies (Brown et al., 2021). While having the MTED directly plant a contingency, such as common student errors known to perplex novice mathematics teachers, is one possibility (see Baldinger et al., 2021; Campbell et al., 2020; Shaughnessy & Boerst, 2018), within such approaches, there is a real possibility for teachers (including beginning teachers) to be embarrassed if they mishandle the contingency (e.g., outing themselves as unable to appropriately handle a common misconception or even having the same misconception themselves). In these cases, it may feel quite natural for the PST to turn to the MTED, rather than their peers, to help them resolve the challenge. However, when the MTED makes the issue clear (e.g., by telling the PST directly that they have a misconception or that they mishandled the situation) it can make the PST feel quite uncomfortable (see Baldinger et al., 2021). In our own work, we have represented such contingencies in the form of storyboard frames for inservice teachers to deal with in the context of their work (Brown et al., 2021). For example, we have provided inservice teachers—operating within this same temperature conversion problem—the opportunity to handle the same misconception displayed in Yellow's work. On numerous occasions, we have observed inservice teachers display the same misconception shown in Yellow's work (i.e., scripting actions that shows the teacher evaluating proportional reasoning as correct for this problem). Crucially, we have also observed those same teachers come around to realize—through their interactions in the Story*Circles* processes—that proportional reasoning does not work for this problem. We suggest that this alternative way of receiving feedback—from their interactions with the milieu and other teachers—has some important advantages for not alienating or embarrassing teachers by being told directly by a facilitator that they have a misconception or inappropriate way of handling a misconception.

The field of education has historically focused too heavily on the preactive phases of teaching and devoted much attention to pedagogies of investigation without considering the benefits of pedagogies of approximation. The recent emergence of new forms of approximation is a step in the right direction for the field of education. That said, the burgeoning development of new forms of approximation can be overwhelming for teacher educators in the field trying to decide how to allocate resources as they seek to adopt innovative pedagogies (see Sweeney et al., 2018). For these reasons, we close by suggesting that this development of new forms of approximation needs to be accompanied by research frameworks capable of illuminating the potential of these various innovations. We offer the Dual Action Cycles of Approximations of Practice to facilitate a step in that direction.

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