Adapting Mathematics Curriculum-Making: Lessons Learned From/With Elementary Preservice Teachers for Curriculum Research

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Abstract

This paper offers insights into how mathematics education researchers can learn from preservice teachers (PSTs) by building upon parallels between adapting curriculum-making and designing research. The pandemic created learning opportunities for PSTs to anticipate mathematics curriculum anew and obstacles for researchers to study their pedagogical processes. A multiple case study reveals how PSTs in Year 1 and Year 2 of a Bachelor of Education program reimagined their intended mathematics curriculum to meet the demands of the evolving pandemic context. Viewed through the lens of complexity thinking and conceptions of *currere* and curriculum-making, PSTs' lesson redesigns include new contexts for teaching and learning (e.g., home environment, parental/guardian involvement, materials) that illuminate how curriculum researchers might become more tentative, responsive, and adaptable to unforeseen circumstances.

Keywords: Curriculum-making, teacher-intended curriculum, preservice teacher education, mathematics education

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Introduction

The Covid-19 pandemic led to school closures and necessitated that preservice teachers (PSTs) adapt their practicum work. Instead of in-person teaching opportunities, PSTs revised their lessons for at-home learning. This presented a dilemma for PSTs as their previous experiences with mathematics education emphasized collaborative problem solving and hands-on learning approaches, which were not always viable in the new context. Complexities emerged for PSTs in supporting students facing learning challenges amidst the stress on mental well-being and personal growth brought about by isolation (McKee et al., 2023). The pandemic's impact on under-resourced families (Armitage & Nellums, 2020) and historically excluded communities underscored the importance of examining issues of equity alongside the shift to designing curriculum for remote learning. At-home learning also raised awareness of the disproportionate access to resources and service across rural communities (McKee et al., 2022). Prepared mathematics curriculum materials, distributed across the provinces, posed challenges for parents and guardians now isolated at home with their children and without teacher support. As teacher educators, we observed PSTs grappling with changes to personal and professional arrangements adding to pressures on their own mental health and professional growth. In our study, we explored how PSTs engaged with these dilemmas, how they sought to improve inclusive practices, and how they pursued avenues to extend innovative approaches to mathematics curriculum design that could support and nurture students' well-being.

Current Study

As a result of the context described above, PSTs faced the challenge of anticipating[1] mathematics lessons for learning at home. This experience exposed dynamics of the teacher-intended curriculum (Remillard & Heck, 2014): meaning teachers' preparations, decision, and actions for enacting curriculum with learners, set in motion under unprecedented circumstances, in turn raised questions for curriculum researchers. Specifically, we wondered: In what ways did the teacher-intended curriculum change in this new context? The entangling of teaching and research for PSTs, teacher educators, and curriculum researchers also created challenges in supporting and documenting PSTs' curriculum design for this changing context. Noticing parallels between pedagogical design and research design, we asked: What can researchers learn from PSTs' lesson plans? And, how does teacher-intended curriculum design inform research methods design*?*

The new contexts prompted us to question how responsive we could become by considering what we might learn from these events and potential new possibilities arising for research. We

[1] Like Davis et al. (2015), we use the term *anticipating* to acknowledge that "teaching is complex and demanding and requires extensive preparation – as much in the form of anticipating emergent possibilities as planning lessons, collecting artifacts, and selecting resources" (p. 156).

draw from data of PSTs' curriculum-making (Priestley et al., 2012) in elementary mathematics focused on supporting home-learning. Curriculum-making denotes a dynamic process whereby commonplaces (i.e., students, teachers, curriculum materials, and learning spaces) all contribute to the making or constructing of meaning. In this article, we illustrate the lessons learned from/with PSTs for curriculum anticipating with the purpose of showing how PSTs' curriculum-making processes brought forth research-making processes to illuminate future teaching and research possibilities.

Pandemic Context

School closures experienced in communities marked unprecedented disruption for students and teachers. We note significant and yet unknown impacts on PSTs, students, and families brought about by the lockdown measures. Complexity thinking helped us make sense of this unique context and the constraints imposed on families. From this perspective, we considered the conditions that promote the emergence of a complex learning system (Davis & Simmt, 2003) as those within it adapt and co-evolve in response to their changing context. These minimum conditions include:

- internal diversity (PSTs, students, and family members all contribute differently);
- redundancy (PSTs, students, and family members all connect with "taken-as-shared" [Cobb et al., 1992] knowledge and share common experiences);
- decentralized control (school communities reorganize and self-organize in response to new constraints);
- organized randomness (PSTs and families seek equilibrium or balance amidst diversity and redundancy);
- neighbour interactions (PSTs and families enjoy opportunities and share ideas that affect the other's activities).

We acknowledge that shifting to at-home learning for PSTs was not about transferring prior knowledge of in-person instructional strategies. Instead, this shift created opportunities for PSTs to self-organize and adapt along with the school community now decentralized across diverse households and to emerge wholly changed or, stated in terms of complexity, greater than the sum of its parts.

Theoretical Framework

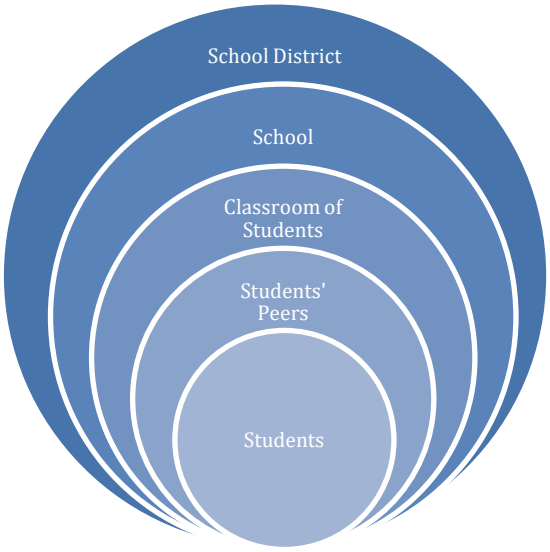
This study describes conceptions of elementary mathematics curriculum-making for at-home learning among PSTs who reimagined their instructional design during the pandemic in concert with the impact of redesign on our research methods. Previously (Throop Robinson et al., 2022), we examined how PSTs created exploratory and playful lessons for hands-on mathematics learning at home. Here, we draw on theories of complexity and curriculum to

inform how researchers might respond to external factors affecting their projects and adapt research to capture unanticipated ways of thinking and knowing.

Complexity thinking recognizes how knowledge emerges through the interactions of those comprising a system that is responsive to the environmental factors that surround it (N. Johnson, 2009). Complex systems are naturally adaptive and emergent, allowing them to achieve levels of systemic complexity otherwise unachievable by individuals acting alone (S. Johnson, 2002). In nature, numerous complex systems abound (e.g., beehives, ant colonies, flocking birds, school of fish). Learners, classrooms, schools, and districts also form a learning system (see Figure 1). Each level of the nested system displays self-similarity to the whole and so retains its complexity despite the level of magnification (Throop Robinson, 2018).

Figure 1

Nested Levels of Complexity Within a Complex Learning System



As researchers (and teachers and instructional leaders), we retain this complexity and remain viable as educators in our adaptability to factors affecting the system. We build a theoretical framework at the intersection of complexity thinking and curriculum design drawing from Davis and Sumara's (2006) work that described the nested relationships of those involved in the learning system. They highlighted these multi-faceted relationships (e.g., among students, educators, teacher educators, families, etc.) interacting alongside uncertainty and changes to the environment to form an emergent system, meaning a vibrant system capable of creating complexity greater than the individual components making up the system.

The impact of school closures brought unprecedented uncertainty to educators and new perspectives on teachers' intended curricula and design. We drew on conceptions of curriculum

as *currere* (Doll & Broussard, 2002) to include the actions of a pedagogy of practice—visioning, doing, and reflecting—to highlight the dynamic nature of curriculum design and re-vision. Complexity thinking invites teachers and researchers to anticipate curricular possibilities rather than plan conventional projects thus allowing for emergent curriculum (Davis et al., 2015; Doll et al., 2006) that is fluid, changing, and adaptable to external conditions in the environment.

Viewed through complexity thinking, responses to the challenges of a pandemic affecting the learning system environment are neither universal nor definitive; rather responses emerge as those within the system adapt to remain viable. This prompted us to consider how our mathematics education research, PSTs' curriculum-making decisions, and our growing pedagogical awareness might co-evolve through the pandemic constraints and emerge changed and renewed. To understand more fully what Khirwadkar et al. (2020) call "emerging mathematics education realities" (p. 42), we answer their call for researchers to, "engage with the evolving mathematics education environment and community by innovating and reimagining their research tools and techniques" (p. 42).

Relevant Literature

Our literature review highlights conceptions of curriculum and curriculum-making viewed through complexity thinking. We begin by elaborating our theoretical approach before synthesizing current curriculum literature. We conclude with emerging literature on the impacts of the pandemic on teacher education and research.

Complexity Thinking and Curriculum Research

Complexity thinking is useful to this study as it informs how we view relationships among researchers, PSTs, and the intended curriculum emerging and evolving from environmental factors (Millar & Osborne, 2009). Distinct from complicated systems (e.g., mechanical devices) that might be taken apart and reconstructed, complex systems with people like teachers, PSTs, and researchers interacting together maintain their complexity when viewed at multiple levels and exist in a dynamic state called disequilibrium (Cochran-Smith et al., 2014). Disequilibrium is necessary to maintain a dynamic complex system that is constantly learning and changing, and helps conceptualize our research considering the disequilibrium brought about by the pandemic. Fels (2004) described PSTs' disequilibrium in coming to understand pedagogy and learning as emergent—uncontrollable and co-evolving. This prompted us to consider new and emerging possibilities for PSTs and researchers arising from unpredictability.

Mathematics Education Research

Mathematics education research typically involves a unique relationship between teacher(s) and researcher(s) who will schedule classroom visits, interventions, or observations (Bostic et al., 2021) to generate data. The tensions of this relationship are well-documented (Chapman, 2012; Llinares, 2021). Complexity thinking illuminates this relationship as the entangling of teaching and researching with each side informing the other (Potari, 2012). On the one hand,

PSTs bring forth unique questions from field experiences (e.g., What practices are effective now? How will I engage my students from a distance? What are my expectations for students during lockdown?). On the other, scholars comment on the generative nature of research (Proulx, 2015) and offer advice, support, and encouragement to stimulate redesign and re-vision of conventional practices (Barabé, 2023). Complexity thinking asks researchers to inquire about emerging possibilities and how experiences might be different given how the system changes and evolves.

Currere and Curriculum-Making

Currere, a fluid vision of curriculum-making, creates new curricular pathways (Varela et al., 2017) and embraces unpredictability and uncertainty in practice. Curriculum, viewed as currere, becomes a verb and a dynamic process engaging all participants. We understand curriculum as a multi-layered social practice brought forth at multiple sites across a complex learning system (e.g., classrooms, schools, districts). Priestley and Philippou (2018) use the metaphor of a spider constructing a web to convey the complexity of curriculum as a dynamic, interconnected, and purposeful process.

Complexity thinking informed our view of curriculum-making during school closures and the shifting dynamics of four commonplaces: milieu, subject matter, teacher, and learner (Priestley et al., 2012). As curriculum-makers, PSTs interpreted and transformed programmatic curricula in response to an unpredictable environment using experiences from methods courses and their emerging professional knowledge. The teacher-intended curriculum (Remillard & Heck, 2014) documents what the curriculum-maker wants to do with students. The teacher-intended curriculum states the lessons' objectives, purposes, and instructional moves. As Remillard and Heck (2014) attest, "this form of curriculum is also the most difficult to access for study because it exists in its most detailed state in the teacher's mind" (p. 711). To meet this challenge, our research freezes the teacher-intended curriculum firstly as pre-pandemic lessons designed for in-person teaching and secondly as redesigned lessons anticipated for at-home instruction. We observed changes and adaptations in the moment as PSTs reconsidered curriculum-making in an unfamiliar context. Further, PSTs' reflections about their processes provide insight into the challenges of curriculum-making during dynamic conditions.

Pandemic Impacts on Education and Research

School closures left an undeniable impact on students, teachers, and researchers. The changing landscape of teaching and learning brought new considerations for all, including students (e.g., accessing a new classroom online, connecting socially with peers, engaging with parents and guardians as instructional leaders); teachers (e.g., designing intended curriculum, enacting curriculum through virtual platforms, co-teaching/planning with parents and guardians in

mind); and researchers (e.g., observing students and teachers without access to conventional research sites, documenting pedagogical changes). Those within the complex system found it necessary to reconceive relationships and reconsider roles played in teaching and learning (Ramploud et al., 2022).

Kamanetz (2020) coined the term "Panic-gogy"—conflating panic and pedagogy—to acknowledge challenges facing education systems and describe the emotional toll and "profound changing of the whole cultural system in which teachers live and work" (Ramploud et al., 2022, p. 536). Panic-gogy refers to teachers' reaction to their students' challenges for at-home learning including their well-being, access to hardware and connectivity, as well as the home environment and support from family members. Panic-gogy acknowledges the teachers' emotional state and uptake of new pedagogical approaches within a fluid pandemic context (Engelbrecht et al., 2020). Acknowledging these impacts invites researchers to question how to adapt current research methodologies to support PSTs. Emerging literature in this area suggests new focus on adaptable methods for PSTs and researchers as we "expand the notion of a classroom to an environment where students could direct much of their own learning" (Engelbrecht et al., 2020, p. 823).

Strict measures aimed at protecting the health of students, teachers, and communities highlighted profound inequities (Hodgen et al., 2020). Commentaries on the impact of school closures on students from economically diverse or underrepresented communities as well as from students lacking parent or guardian support document these challenges (Aguirre, 2020; Ewing, 2020). Bakker et al. (2021) called for additional research to consider anew the relationships among mathematics education, school, and home communities with an emphasis on equity, diversity, and inclusion (EDI) as the drivers for redesigning pedagogical approaches and research methodologies. This resonates with our research where PSTs raised concerns about EDI issues observed in their home communities and offered potential instructional approaches to address them.

Methodology

Research Design

This study was conducted within a 2-year teacher education program in eastern Canada and focused on an alternate practicum where PSTs completed lesson-planning and reflection assignments. Our emergent design used multiple case study methodology (Yin, 2014). This multiple case is comprised of two cases, with each case bound by the assignment work of the alternate practicum for Year 1 and Year 2 PSTs. Under ordinary circumstances, PSTs would complete their field placement teaching working closely with an Associate Teacher and a class of elementary students. When schools closed, PSTs could not proceed as scheduled and,

instead, engaged in an alternate practicum that required the redesign of the original pre-pandemic lessons (Task 1) anticipated for the grade level originally assigned for practicum (see Table 1). The lesson redesign (Task 2) would anticipate and support at-home learning opportunities for students. Fully recognizing that parents and/or guardians could be considered students' first teachers, PSTs imagined new possibilities for learning while families were isolated, and students restricted from social and peer interaction. To complete the alternate practicum, a follow-up assignment (Task 3) involved reflecting on the rationale for the ways in which lessons were redesigned and learning at home anticipated. The detail and length of these tasks varied according to the PST's year in the program (where Year 1 PSTs were expected to create more simplified plans than those in Year 2, to reflect different experience levels in coursework and school-based practicum). The PSTs' alternate practicum assignment work became the body of data for this multiple case study.

Table 1

Alternate Practicum Tasks: Bachelor of Education

EDUC 472 (Year 1)	EDUC 482 (Year 2)
Task 1: Planning (weeks 1 & 2): March 23–April 3 (due April 1–3, 2020)	
All Year 1 students should: 1. Communicate with their Associate Teachers so that they can know what classes they would normally be teaching in the 2-week period beginning Monday, April 6; and 2. Prepare all lesson plans for this 2-week period (at 50% of a normal teaching load) and share these plans with their Faculty Advisor no later than Wednesday, April 1. • These lesson plans should be written in detail—in digital format with digital links to necessary/supporting materials (e.g., PDFs, videos, etc.). Essentially, these lesson plans must include all materials necessary to teach them.	All Year 2 students should: 1. Communicate with their Associate Teachers so that they can know what classes they would normally be teaching in the 2-week period beginning Monday, April 6; and 2. Prepare two unit plans and all lesson plans for this 2-week period (at 100% of a normal teaching load) and share these plans with their Faculty Advisor no later than Wednesday, April 1. • These unit and lesson plans should be written in detail—in digital format with digital links to necessary/supporting materials (e.g., PDFs, videos, etc.). Essentially, these unit and lesson plans must include all materials necessary to teach them.

Table 1 (cont'd)

Alternate Practicum Tasks: Bachelor of Education

EDUC 472 (Year 1)	EDUC 482 (Year 2)
Task 2: Out-of-school Learning (weeks 3 & 4): April 6–17 (due April 15–17, 2020)	
All Year 1 students should: 1. Select 10 lesson plans (or 10 lesson plans' learning outcomes) from Task 1; and 2. Develop 10 out-of-school learning experiences (lessons) for students (these could be digital/online and/or "low-tech" distance activities). • Basically, students should aim to take "normal" and already-created in-class lessons and create out-of-school learning experiences, as possible (clearly, some elements will change, though learning outcomes should remain). • These out-of-school plans should include all materials necessary for students (and parents/guardians, as appropriate). • Also, students should identify an exemplary out-of-school learning activity from these 10 (i.e., the "best" one).	All Year 2 students should: 1. Select one unit of 10 lesson plans (or 10 lesson plans' learning outcomes) from Task 1; and 2. Develop a unit with 10 out-of-school learning experiences (lessons) for students (these could be digital/online and/or "low-tech" distance activities) • Basically, students should aim to take "normal" in-class lessons and create out-of-school learning experiences, as possible (clearly, some elements will change, though learning outcomes should remain). • These out-of-school plans (unit plan included) should include all materials necessary for students (and parents/guardians, as appropriate) as well as relevant assessment plans (depending upon discipline and grade level). • Also, students should identify an exemplary out-of-school learning activity from these 10 (i.e., the "best" one).
Task 3: Reflection (weeks 5 & 6): April 20–May 1 (due April 29–May 1, 2020)	
All Year 1 students will write a 5–7-page reflective paper where they: 1. Share the challenges and opportunities related to shifting to out-of-school learning experiences (e.g., with respect to planning and inclusion). 2. Identify their "most-useful" resources for such a shift. 3. Provide an overview of their exemplar's potential and strengths.	All Year 2 students will write a 5–7-page reflective paper where they: 1. Share the challenges and opportunities related to shifting to out-of-school learning experiences (e.g., with respect to planning, inclusion, assessment, and special needs). 2. Identify their "most-useful" resources for such a shift. 3. Provide an overview of their exemplar's potential and strengths.

Participants

The participants, 26 elementary (K–6) PSTs, had completed two mathematics methods courses which modelled a relational pedagogy and problem-solving approach (Liljedahl, 2020). Recruitment for the study began after PSTs had completed their course work, practicum requirements, and grades had been submitted. We obtained approval from the university research ethics board prior to recruitment. We distributed letters of invitation to participate upon receipt of the ethics to explain our intent, the project's voluntary nature, and confidentiality. From the group of voluntary participants, 11 PSTs were studied because of their curricular focus on mathematics: six Year 1 students and five Year 2 students (see Table 2). As PSTs were no longer enrolled in classes, they were assured that grades would not be affected by nonparticipation. We informed PSTs that data sources for the study would include their lesson materials (e.g., notes, images, web-based materials, and digital resources created by PSTs) and their written reflections. We communicated that we would de-identify all data and use pseudonyms in all scholarly publications and conferences.

Table 2

Participants' Demographic Information

Pseudonym	Gender	B.Ed. year	Grade level	Curriculum
Debbie	F	1	6	Mathematics
Karen	F	1	5/6	Mathematics, Social Studies
Gina	F	1	3	Mathematics, Science
James	M	1	K–6	Mathematics, Physical Education
Lucas	M	1	3	Mathematics, English Language
Tess	F	1	3	Mathematics, English Language
Brenda	F	2	6	Mathematics, Science
Hannah	F	2	4	Mathematics, Science
Joy	F	2	6	Mathematics, Science
Regan	F	2	5	Mathematics, English Language
Troy	M	2	5/6	Mathematics, English Language

Data Collection

We collected data through the university's Moodle learning platform. PSTs uploaded their assignments (i.e., lesson designs, redesigns, and reflections) to the secure classroom site as part of their regular course work. Researchers alone had access to the assignments. Only those assignments from PSTs selected for study with signed participation letters were downloaded for analysis after grades were submitted. The following timeline (see Table 3) indicates key phases of data collection and analysis.

Table 3

Study Timeline

Date	PSTs	Researchers
March 2020		
• Planning (weeks 1 & 2): March 23–April 3 (due April 1–3)	• Pre-pandemic practicum assignment (Task 1) completed and submitted through Moodle	• Pre-recruitment evaluation of practicum assignment (Task 1)
April 2020		
• Out-of-school learning (weeks 3 & 4): April 6–17 (due April 15–17)	• Pandemic alternate practicum assignment (Task 2) completed and submitted through Moodle	• Research Ethics Board approval • Alternate practicum assignment (Task 2) downloaded from Moodle and de-identified
May 2020		
• Reflection (weeks 5 & 6): April 20–May 1 (due April 29–May 1	• Pandemic alternate practicum assignment (Task 3) completed and submitted through Moodle	• Alternate practicum assignment (Task 3) downloaded from Moodle and de-identified
June–July 2020		• Recruitment of participants • Participant selection • Data analysis

Data Analysis

We uploaded 213 files from lesson plan documents, written reflections, supplementary teaching materials, and instructional resources to a shared secure folder. We used document analysis methods to compare document drafts, statements, and phrases including fragments and/or groups of statements from these texts and track development as "even subtle changes in a draft can reflect substantive developments in a project" (Bowen, 2009, p. 30). This resonated with us from a complexity perspective where small, incremental changes in a learning system may give rise to dramatic results and even bring about greater than expected outcomes (Doll et al., 2006). Examples of statements taken from the redesigned lesson data set and PSTs' written reflections are: "I am going to look at the positives of this situation, such as learning new strategies for online teaching, communication skills, peer collaboration and including parents/guardians in the learning process of their children" (James), and "In my experience, I was overcome with uncertainty as I attempted to construct out-of-school instruction" (Debbie).

Qualitative Validity

The analysis method was recursive with each researcher categorizing data by grade level and curriculum (e.g., Mathematics, English Language, Science, Social Studies) before reading the data multiple times and noticing "segments of data that might be useful (Merriam & Tisdell, 2016, p. 204). We first coded data segments, grouping open codes and forming potential categories of recurring patterns (Charmaz, 2014). We identified themes individually and then shared them, noticing areas of resonance and dissonance. Through multiple discussions, we agreed upon emergent themes that recognized how PSTs redesigned lesson plans and responded to pandemic-related challenges and opportunities. The teacher reflections provided context for the decision-making involved in revising lessons for at-home learning as well as insights for the researchers into the parts PSTs played as the learning system changed, adapted, and evolved. Together, we categorized themes and grouped subthemes to construct propositions for this multiple case (Baxter & Jack, 2008). Returning to our propositions multiple times through an iterative process (Yin, 2014), focused our analysis and increased the generalizability of the study. This process also increased our confidence in the findings that show how PSTs reimagined their intended mathematics curriculum, reconsidered how students access and engage in learning, and repositioned parents/guardians as partners to meet the demands of the evolving pandemic context.

Findings

Our findings describe how PSTs reimagined their intended mathematics curriculum. This involved reconsidering how students might access instruction and learning materials as well as engage in learning at-home. The findings also describe how PSTs repositioned parents/guardians as partners to meet the demands of the shifting pandemic context. The data

suggest that while all PSTs designed the intended curriculum for in-person instruction with their students (Task 1), many experienced challenges in redesigning their intended curriculum for at-home learning (Task 2). PSTs responded to these challenges by reconsidering the curriculum commonplaces as they became fluid and adapting their curriculum-making to respond to new and unfamiliar contexts. We considered how questions arising for PSTs designing their intended curriculum paralleled an emergent research design that supported new possibilities and implications for curriculum researchers. This provided strategies for PSTs to embrace new perspectives in curriculum-making and for researchers to consider research-making.

Our findings trace evidence of PSTs engaged with dilemmas arising from the pandemic, namely reimagining their curriculum-making by adapting to the evolving commonplaces for learning. We begin with one of the biggest challenges for some PSTs—a shift in milieu brought about by school closures. Next, we take up the challenges presented to PSTs in terms of teacher, student, and subject matter as they are woven together in the three tasks of the alternate practicum. We show how PSTs responded to curricular dilemmas by expanding each of these commonplaces to include new places, new curricula, new materials, and new people. Embedded within the examples are the PSTs' beliefs about curriculum-making, pedagogy, assessment, and the deep concern they held for the wellness of their students and other family members in the home environment. From these findings, we draw parallels between how PSTs adapted their curriculum-making for new learning and how we adapted our research in the new pandemic environment. We take up the implications for research-making and detail how they impacted our emerging research design in the Discussion section that follows.

Reimagining the Intended Mathematics Curriculum in a Changing Milieu

PSTs recognized the challenges of redesigning their intended mathematics curriculum for at-home learning without fully understanding how students would be supported in the home environment, what materials might be available, and whether families had access to computers or connectivity. Shifting from Task 1 to Task 2 in the alternate practicum required PSTs to draw upon their previous course work, school experiences, and their own creativity to reimagine the curriculum and address evolving EDI issues. For example, Debbie reflected:

> I did not definitively know my learners' needs and demands at home; I did not know the resources they had accessible to them; I did not know where they were located and the available space they had to learn. Due to this uncertainty, I found myself worrying for my students' well-being and their overall academic development during this time.

Lucas echoed this with his reflection:

> As a result of this novel situation, there lacks any precedent and decisions are made

> reactively, which is not to imply that decisions are not being made deliberately or being well thought out, but rather that there was initially no plan for an event like this.

Similarly, as researchers, we recognized the challenges presented to the PSTs without fully understanding how they would respond to the new context. To continue our research with PSTs despite school closures, we reimagined our data sources and, through document analysis, began to shed light on how emerging educators responded to pandemic challenges.

PSTs worried about their responsibility toward the provincial curriculum and the nature of the tasks they designed for at-home learning. Gina stated, "The mathematics curriculum provides an extensive list of lessons that I need to adapt to being home." Brenda reflected on her emerging insights about the curriculum: "The curriculum is what you have to teach, but it doesn't say how you have to teach it. It is up to teachers to make those choices on how we will help our students learn." Tess also stated, "This was a very hands-on lesson plan which involved students using physical objects around the home to create arrays and show that it is multiplication. Students are encouraged to go outside and find examples of arrays in nature, or their household." PSTs reflected on embracing learning environments and changing milieu by adapting to time and space in their curriculum-making. Their concern for expanding their professional gaze to include new places inside and outside the home in a new milieu shaped their lessons as curricular concerns shifted to "big ideas" (Troy) and "simplified tasks" (Joy). Hannah reflected, "I was always thinking about their home environments such as their families, access to technology and access to any other materials that are required to complete the specific activity" and offered choice and challenge to students by exploring the physical spaces at home through an "Area Math Scavenger Hunt." As teacher educators and researchers, we too reflected on the shifting commonplaces (i.e., milieu, subject matter, learners, teacher) and what this would mean for PSTs nearing the end of the academic term without access to their classrooms. Rapidly transitioning to the alternate practicum provided a means to fulfill provincial expectations for PSTs and adapt our research expectations to the pandemic context. We next identify how PSTs met the challenge of changing subject matter as they redesigned their intended curriculum.

Reconsidering How Students Access and Engage in Learning the Subject Matter

PSTs sought to improve inclusive practices for students even as they were staying home without peer or teacher interaction. PSTs recreated and adapted formats in their lessons to pursue avenues to extend innovative approaches to mathematics curriculum that could support EDI issues and nurture students' well-being. For example, Troy reflected on the constraints and affordances of lesson plan structures and templates while creating his at-home learning package:

> When creating my out-of-school experience, I wanted to structure it as something that students can jump in and out of, but still have the structure of math tasks, small spots of

> reflection and direction for students. The best or realistic way to approach students learning throughout out-of-school experiences is we as teachers need to be adaptive to the different reality's students are in. I thought of ways of providing math content in three different forms for students, this was through visual, audio means (videos, pictures) and through literacy (articles).

Lucas spoke to family support, EDI, and accessibility issues for students when reconsidering how students would engage in learning at home:

> There is the issue of human resources. Will students have someone around the house to help them with schoolwork during the day, or only select hours? Then the matter of educational content … available to students in an accessible way (different modes of presentation for different learners—if they are tactile learners, is there something for them to physically handle? If they are auditory, are there understandable audio instructions for them?).

These questions parallel similar questions posed as researchers to respond to changes in subject matter for our participants and to modify our research focus. In what ways do PSTs respond to and meet the new challenges facing mathematics educators? What adaptations emerge in the subject matter for PSTs?

Intermingled with a shifting subject matter for PSTs was concern over access to technologies and the challenges facing students, families as well as themselves regarding service and availability of computers in the home. Regan stated:

> I attempted to provide a variety of options with specific online links to how they could make their own [tangrams] with a variety of common materials they may already have at home. … Around the same time, I started to receive the home-schooling lessons for my daughter from her teacher and realized that less really is more.

Some PSTs considered low-tech options in lieu of insufficient or unstable connectivity. This was the case for Lucas:

> The [fraction] lesson is low tech; students are making these themselves, using whatever paper they can find at home, colours if they wish, pencils and scissors (though it is not even necessary to actually cut the cards out—if they were really in a situation where they have no access to scissors, they could use full sheets). Further, the lesson is naturally differentiated; students can make the fractions as simple or as complex as they are able to visualize or observe in the world around them.

For other PSTs, their lessons expanded to include digital platforms, virtual tools, and online resources to meet the needs of the changing commonplaces.

The changing subject matter concerned teacher educators and researchers as PSTs were shut out of schools and required to rethink how to bring mathematics education to students learning at home. Our research design required modification to acknowledge not only how PSTs would adapt the subject matter to suit learners' new needs but also how PSTs adopted new sets of pedagogical awareness and responsibilities in their subject matter. We opted to adapt to this changing subject matter for PSTs and explore the many ways they responded to the unprecedented circumstances with new outlooks on teaching and learning. We next document PSTs' account of the teacher's shifting role during school closures.

Repositioning Parents/Guardians as Partners With Learners

PSTs recognized the changing environment for students brought about by the pandemic restrictions as well as the changing environment for themselves as emerging teacher professionals. PSTs noted the dynamic teacher commonplace shifting from the conventional teacher in the classroom to adults, guardians, parents, or other family members including significant, more knowledgeable others in the home. Some described leveraging partnerships with parents as renewed conversations about the emerging role of the teacher occurred. Debbie reiterated her goal for students at home: "This lesson particularly demonstrated my drive to incorporate parent-child relationship building into activities, undoubtedly enriching students' overall education and academic development." In her reflection she elaborated on the role of the teacher:

> As a student for over half my life, I had assumed that specific courses had set criteria for the way things had to be done to reach the learning goals and didn't think a lot about the role of the teacher in structuring learning activities or finding culturally relevant and appropriate resources.

Tess further acknowledged the challenges facing teachers and families:

> Passing the reigns to the guardians to teach your lessons is a hurdle that is not quickly remedied. As a teacher you know how you want to teach this lesson that you have planned, you know how your class will react to it, you know how to make it engaging, and you know how to help students without just giving away the answer.

Karen considered the impact on students in her reflection and shifted to the perspective of the learner:

> You really have to put yourself in the child's shoes and thinking about what I would have wanted if I didn't have my teacher there to help me. … You really had to dig deep here and find a way to include all students and I tried to make my lessons follow a universal design for learning but I am aware that I did not always do that and that is something I need to work on in the future!

Many PSTs were moved to state the positives they could find in unprecedented circumstances. James reflected: "I am going to look at the positives of this situation, such as learning new strategies for online teaching, communication skills, peer collaboration and including parents/guardians in the learning process of their children." Lucas spoke of the many changes brought to curriculum-making in the teacher and learner commonplaces:

> For all the challenges the situation poses, there are also possible benefits to at-home-learning as well. Students may get greater one-on-one attention from the people who know them best—their parents or family members. They will have the chance to learn in an environment that is familiar to them and can learn at their own pace.

As researchers, we strived to remain positive and seek out new opportunities arising from an unconventional situation. We also saw our relationships with PSTs in their formative years changing and developing as reciprocal partnerships. In our conversations, we acknowledged the growing nature of these relationships with our participants as we shared experiences of frustration, isolation, and anxiety over the health and well-being of our respective learners. The statement from one of our participants to families, "We are in this together," also resonated for us as restrictions isolated us from each other. This phrase spoke to the parallel nature of our teaching and research and served to remind us that we had just as much to learn from our PSTs as they had to learn from us.

The findings offer insights into how PSTs adapted their intended curriculum to meet new conditions, shifting commonplaces introduced into the learning system, and EDI issues. PSTs met uncertainty and unease surrounding their curriculum re-design with professionalism, thoughtful consideration for students and their families, and openness to adapt to shifting dynamics within the education system. PSTs' uptake of these challenges parallels the researchers who also responded to changing commonplaces and pandemic constraints in new ways. In our discussion we respond to these themes to consider the implications for educational researchers of lessons learned from PSTs adapting curriculum-making and to make connections with our emerging research design

Discussion

In this paper we shared how PSTs completed three tasks of an alternative practicum assignment focused on adapting lessons for at-home learning. School closures meant PSTs would not have access to their school sites or their students; however, they would experience curriculum-making in diverse ways and offer valuable insights to researchers in the process. Conceptions of complexity thinking acknowledging the co-activity of those operating at multiple levels within a learning system (Davis & Simmt, 2003) guided our inquiry. Our results illustrate the intersections of teaching and research as PSTs engaged in curriculum-making to redesign their

intended curriculum and we, as researchers, closely attended to PSTs' curriculum-making to reimagine our research design. As well, we consider how PSTs expanded their intended curriculum to include new people, new materials, and new ways of looking at curriculum just as researchers adapted data sources and expanded their perspectives to leverage curriculum-making processes to inform research. In this section, we trace the ways PSTs designed, adapted, and reflected upon their intended curriculum. Informed by complexity thinking and mindful of the co-implicated and co-evolving contributions of participants within the learning system, we connect the PSTs' redesigns, adaptations, and reflections with implications for our emerging research design.

Curriculum-Making and Research Intersections

The pandemic exposed shortcomings of more traditional/conventional approaches to curriculum research and the need for new methodological perspectives to adapt to the rapidly changing climate in education (Khirwadkar et al., 2020). School closures and quick pivots to at-home learning made visible what Lucas described as "the unpredictability of outcomes despite being well thought out." From a complexity perspective, the uncertainty and lack of prescriptive action opened new spaces of possibilities for teaching and research and illuminated the interconnectedness of the learning system. Significantly, PSTs adopted a proscriptive approach to curriculum-making in response to shifting commonplaces. Subsequently, researchers adopted a similarly proscriptive approach to research-making as our design became fluid. For PSTs, their anticipated lessons became more tentative and exploratory by taking a "what might happen" approach rather than a preplanned agenda. Recognizing the intersection with curriculum-making, we began redesigning our methodologies with a more tentative regard toward the changing milieu for PSTs and how they endeavoured to explore the subject matter of mathematics education in new ways for at-home learning.

PSTs engaged with dynamic curriculum design in response to moving to a learning-at-home context. Their intended curriculum was fluid, set in motion by expanding to include the home environment, parental/guardian involvement, and new materials. Brenda's reflection above on the choices teachers make regarding curriculum illustrates her shift from thinking about curriculum as a noun toward thinking about curriculum and curriculum-making as verbs. PSTs came to understand new curricular pathways as currere, the actions of a pedagogy of practice or process in constant flux through visioning, doing, and reflecting (Davis et al., 2015; Varela et al., 2017). For researchers, anticipating mathematics curriculum research also became more fluid as we reflected upon new ways to meet the demands of the new context. Without access to classrooms of students for observations or meetings with PSTs, for example, we adapted data sources to include documents and artefacts found in lesson designs and written reflections for analysis. While learning from PSTs in their new roles as educators, we also shifted our focus

towards learning in relationship with PSTs as we encountered new obstacles and challenges together. Collaborative visioning around ways to communicate with and engage learners at multiple levels in at-home learning forged new curricular possibilities for families and pedagogical strategies for PSTs and researchers.

Our Emerging Research Design

We took guidance for our study in PSTs' adaptations by expanding to consider the interconnected and co-evolving commonplaces of milieu, teacher, learner, and subject matter from a complexity perspective. With these commonplaces in flux for researchers as well, our own awarenesses of pedagogies and curriculum design created new understandings for teaching and learning at home. This increased focus on the co-evolving relationships of PSTs and researchers interacting in response to environmental factors as each re-imagined pedagogical and research tools and techniques (Khirwadkar, et al., 2020). The disequilibrium (Cochran-Smith, et al., 2014) felt by many during the pandemic brought forth a new understanding for PSTs of curriculum-making, pedagogy, and learning as uncontrollable and co-evolving (Fels, 2004). From a research standpoint, our analysis of the PSTs' tasks showed a progression through the tasks that had created an audit trail of learning. The task redesign exposed what was most important in the intended curriculum (e.g., seeing big ideas through simplified tasks, making use of unique and individualized environments, attending to EDI), created possibilities for PSTs to imagine pedagogy differently, and opened a space for us to re-imagine research methods and data analysis by distance.

Expanding Understandings of the Intended Curriculum and Research

PSTs expanded their understanding of the intended curriculum in significant ways. Pre-pandemic experiences from on-campus methods courses included looking at current, research-based pedagogies with a focus on students' mathematical thinking using hands-on, interactive methods. PSTs' designs for Task 1 emphasized problem solving over practice as well as in-home learning opportunities with families. The redesigned lessons from Task 2 showed movement on many levels with PSTs expanding their consideration of students' needs and emerging EDI issues not yet anticipated. Troy's reflection in Task 3 on curriculum-making for example showed renewed attention to and concern for the shifting commonplaces. Troy recognized the importance of flexibility in the subject matter (e.g., exploring mathematics through Minecraft) and adaptability to learners' lives through ongoing learning opportunities rather than single events (e.g., self-directed access to multi-modal resources). In complexity terms, Troy's redesign decentered teacher authority and shifted students' accountability for learning towards self-organization thereby expressing more fully his understanding of the complex nature of learning. Similarly, researchers expanded their understandings of how PSTs

designed their intended curriculum while isolated from their peers and colleagues yet fully accountable in their expectations of learners and their well-being.

Our Emerging Research Design

The pandemic created opportunities to expand our research methods to facilitate access to PSTs' intended curriculum (Remillard & Heck, 2014). This included document analysis as a way of freezing what PSTs had set in motion in their curriculum-making. Due to pandemic restrictions, we turned to document analysis and worked collaboratively from a distance to illuminate the thinking and decision-making processes of PSTs in the moment and in response to the changing needs of their students. We used PSTs' reflections to help explain and document their intended curriculum and redesign. Through these reflections we noticed how PSTs emphasized different and changing teacher identities that included stabilizer, partner, and communicator while recognizing the valued role of parent, guardian and knowledgeable other within the home to support learners. While undoubtedly experiencing elements of panic-gogy (Kamanetz, 2020), James, Lucas, and Tess sincerely articulated the challenges of uncertainty facing teachers in caring for learners' mental health, EDI concerns, and inviting partners into new teaching roles through their co-involvement in curriculum-making for at-home learning. As researchers, we drew inspiration from the courage of our participants to meet challenges head on and to seek meaningful alternatives for learning mathematics at home. Consequently, we engaged in adapting our research focus to find meaningful ways to acknowledge our participants' learning needs for their intended curriculum and the evolving pedagogical challenges of at-home learning.

Strengths and Limitations

Our findings describe creative and innovative responses from PSTs to re-imagine curriculum-making for engaging and meaningful at-home learning activities. PSTs demonstrated resourcefulness, attention to detail in materials, resources, and ease of access for all students as well as care for students' well-being. We make connections and draw insights from PSTs' endeavours to adapt their intended curriculum. Within our co-evolving relationship, we see greater opportunities for curriculum-making with renewed passion for supporting students' learning in unfamiliar contexts and with new perspectives on commonplaces. Additionally, our findings show that a complexity perspective (Doll et al., 2006) yielded insights into our emerging research design that is flexible, open to change, and responsive to context and participants.

We also identify limitations to our study. A select sample size limited the data collected from PSTs. Future studies with a broader sample size may contribute further insights. The stresses and anxieties due to school closures and an unsettling, unprecedented term impacted the lives

of PSTs in different ways. We acknowledge the professionalism and grace of all PSTs in navigating this uncharted territory to complete their alternate practicum and also volunteer their efforts as part of this research study. We value their contributions and willingness to share the implications of such events on professionals and researchers who prepare for future, post-pandemic research.

Concluding Thoughts

PSTs voluntarily involved in this study found new ways to adapt and expand their understandings of curriculum-making as they sought to redesign lessons for at-home learning. We have outlined a reimagining of the PSTs' work and shared possible considerations for mathematics education research to adapt to new learning and instructional environments. For example, as PSTs adapted their intended curriculum with EDI concerns illuminated through the pandemic, so too might researchers consider EDI as drivers for redesigning research methodologies in response to these critical factors. Paying attention to shifting commonplaces and environmental concerns affecting participants within the learning system means providing flexibility and adaptability at every turn with a view to being responsive to changes rather than reactive. As complexivists understand, even slight changes to a system have the potential to bring forth large-scale implications for participants within the system.

Together with PSTs, we acknowledge new perspectives gained on curriculum-making including recognition that curriculum cannot be fully predesigned. Rather, curriculum-making requires adaptability and responsiveness to students' needs and dynamic environments. We applaud the fortitude and creativity of PSTs who persevered to bring the best possible learning experiences to their students during challenging times. Their adapted curriculum-making provided context for our research-making as we became more responsive to shared commonplaces including teacher knowledge of and beliefs about the subject matter, understanding of learners' needs, changing roles for teachers, and shifting milieu for learning. With these considerations in mind, designing curriculum research could involve renewed focus on teachers adapting curriculum-making with the potential to support and inform co-evolving professional practices and the work of researchers.

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