

Mathematics Pedagogical Design Capacity from Planning through Teaching

Julie Amador
University of Idaho

Received: 12 December 2014 Accepted: 26 October 2015
© Mathematics Education Research Group of Australasia, Inc.

As teachers prepare for mathematics lessons they make instructional plans based on their knowledge and available resources. A teacher's capacity to mobilise resources to design lessons is known as his or her pedagogical design capacity. This study analyses shifts in the pedagogical design capacity of four teachers as they transition from lesson planning to lesson implementation in the classroom. Results indicate that teachers' pedagogical design capacities are reflected differently from the time of lesson planning to the time of instructional delivery, with a shift toward less curricular reliance during implementation. Findings indicate that teachers would benefit from support to know how to make changes, while teaching in ways that will best develop students' mathematical thinking. Additional work focusing on the role of context as related to pedagogical design capacity, would provide further insight for understanding teachers' abilities to use resources for mathematics instruction.

Keywords · teachers · curriculum · lesson planning · pedagogical design capacity · students

Introduction

The process of mathematics lesson design is complex as teachers consider curricular resources, school and district guidelines, and the students they teach. In this process, educators are forced to make decisions about the materials they will use and the extent to which they will use these resources. They make decisions about rationale for planning lessons, often starting with curriculum or identifying desired results (Wiggins & McTighe, 2011). Resources include all supports for planning, defined as artefacts (i.e. curriculum materials) as well as personal connections, knowledge, or understandings (Brown, 2009). Remillard (2005) studied research on teacher curricula use and identified four approaches researchers have taken when describing curricula use: (a) curriculum use as following the text, (b) curriculum use as drawing on the text, (c) curriculum use as interpretation of text, and (d) curriculum use as participation with the text. Of these, less emphasis has been placed on curriculum use as participation with the text, meaning the extent to which researchers focus on the relationship between the teacher and the text. Understanding the nature of the relationship teachers have with texts as they design lessons is important for knowing how they "use, shape, adapt, and interpret" curriculum materials (Remillard, 2005, p. 222).

Beyond knowing how teachers use resources when designing lessons, understanding the role of curricula and how teachers make decisions from planning through lesson enactment is important for clarifying how teachers make changes to materials and how they rely on curricula at various points during the teaching process. Brown, (2009) coined the term Pedagogical Design Capacity (PDC) to describe how teachers offload, improvise, and adapt curricula materials in the lesson design process. However, this work assumed a static description and identified PDC as a constant without examining how teachers make changes from the point of lesson design through delivery. As teachers engage in the process of lesson planning and implementation, it is plausible that their relationship with curricula materials and their PDC may shift. Likewise, research literature has examined teachers as lesson designers by focusing on the role of curriculum in the classroom (e.g. Ben-Peretz, 1990; Clandinin & Connelley, 1991; Remillard, 2005); however, these studies have neglected to consider changes that may

occur in curricula use and teacher conceptions about lessons at various points in the teaching process. To support teachers' instructional practices, it is important to understand their reasoning as they make planning and teaching decisions. As a result, this study addresses one research question:

1. How is the Pedagogical Design Capacity reflected differently in teachers' planning and in their teaching?

Theoretical Framework

Based on the seminal work of Brown (2009), this study is framed with the theoretical construct of PDC and builds on the notion of offloading, improvising, and adapting as a descriptor for interaction with artefacts. Teachers' artefacts for mathematics instruction include curricular materials, such as textbooks that they engage with in the process of planning lessons (Pea, 1985; Shield & Dole, 2012); artefacts are defined as materials created by humans, in this case, the materials are used for informational purposes (Wartofsky, 1973). As teachers use, shape, and mold these artefacts to plan their lessons they generate a relationship with the curricula that influences how they view and perceive resources as a means for instructional implementation (Remillard, 2005; Wertsch, 1988). In this process, "the ways teachers attend to curriculum resources is influenced by...their capacity to competently use curriculum materials to enact particular forms of instruction" (Choppin, 2011, p. 333). This capacity is a teachers' PDC.

PDC refers to teachers' abilities to work with curriculum materials and manipulate them to accomplish specific tasks within a classroom (Brown, 2009). This includes understanding how artefacts mediate instruction and how teachers interpret resources. As teachers begin to plan a lesson, they commonly select materials and then use their knowledge and beliefs to interpret the materials in an attempt to understand how the materials may support instruction (Brown, 2009; Freeman & Porter, 1989; Tarr et al., 2008). While considering the benefits of various materials, teachers should be cognizant of learning goals, affordances and constraints of the situation, and curricular recommendations (Brown, 2009; Remillard, 2005). As some teachers consider lesson implementation, they often accommodate, add, modify, or omit curricular recommendations before arriving at decisions about what to teach and how to teach (Brown, 2009; Remillard, 1992; Tarr et al., 2008). In this process, teachers' use of materials occurs at varying "degrees of artefact appropriation" (Brown, 2009, p. 24), meaning teachers use curricular materials to differing extents. Brown (2009) coined three terms to describe how teachers perceive and mobilise resources to design lessons: *offloading*, *adapting*, and *improvising*. Understanding a teacher's PDC is important for knowing how they interact with curriculum materials because differences may result in sharply contrasted implementation approaches for instruction. The following describes these three modes of curriculum use with the purpose of explicating the varying degrees of artefact appropriation.

Offloading

Based on the work of Brown and Edelson (2003), offloading is described as an interaction with curricula such that the teacher endures a significant reliance on curricular materials, including tasks, worksheets, and pedagogical steps directly from resources. Often, offloading takes place when a teacher lacks confidence in his or her content knowledge related to a mathematics topic and decides that following the curricular materials would result in sufficient lesson outcomes, beyond what would occur if the teacher provided more individual input into the lesson. An example of offloading would be if a teacher were instructing students about how to perform a complex calculation and the teacher relied on scripted instructions to lead students through each step of the calculation while continually consulting a curriculum guide (Brown, 2009).

Adapting

Adapting is on the same continuum as offloading, with a less stringent reliance on curricular materials for lesson implementation. Adaptation results in moderate reliance on tasks, worksheets, and pedagogical steps from curricular materials. An example would be a teacher using curricular materials to initiate a discussion on calculations and inserting her own discussion questions to advance mathematical understanding during the conversation (Brown, 2009). When adapting occurs, the teacher and the curricular materials dictate instructional paths with shared responsibility for design. The act of analysing and adapting materials has been declared a necessity for effective instruction, even when the mathematics curricula are high quality and reform based (Davis, Beyer, Forbes, & Stevens, 2011). In the process of adapting, teachers work to better support student learning, based on the needs of their own students by considering “insertions, deletions, or substitutions” (p. 797) in the materials (Davis et al., 2011). Likewise, Choppin (2011) described *learned adaptations* as adaptations of knowledge based on learned experiences from previous instruction. These adaptations rely on teachers’ knowledge of knowing how to design instructional outcomes to provide opportunities for intentionally strengthening students’ conceptual or procedural knowledge (Choppin, 2011). Ultimately adaptations are described as shared responsibility instances of curriculum design intended to moderate reliance on curricula, to result in effective teaching that targets student needs and specific learning goals (Brown, 2009).

Improvising

Improvisation occurs when teachers assume responsibility for lesson design and dictate instructional paths with little, if any, reliance on curricular materials (Brown, 2009). When improvising occurs, teachers assume self-designed instructional paths as they create instructional tasks or pedagogical steps that deviate from curricular materials. Commonly, improvising occurs when teachers encounter opportunities for continued teaching in the classroom, beyond those recommended in the curriculum, and have the knowledge to assume instructional design responsibility. An example would be a teacher-created plan allowing students to devise their own method for solving calculations, in which the teacher deviated from curricular materials to coach students based on her own knowledge of the content (Brown, 2009). The aforementioned degrees of artefact appropriation span from offloading, to adapting, to improvising along a continuum for examining a teacher’s ability to mobilise resources for instruction and serve as the theoretical framing for this study.

Relevant Literature

Curricular Use

Mathematics education research has examined teacher knowledge with relation to how teachers use curricula, adapt materials, and design plans to understand if teachers are making changes to improve instruction or if their changes are negatively influencing instruction (Remillard, 2005; Sherin, & Drake, 2009; Stein & Kaufman, 2010). Research on curricula reform has found that school leadership and the institutional context can heavily influence practice (Cobb, McClain, Lamberg, & Dean, 2003; Lamb, 2010). Likewise, additional research has focused on how teachers perceive curriculum materials indicating teachers are concerned with meeting curricular objectives, gathering materials, implementing the necessary content, and task selection (Christou, Eliophotou-Menon, & Philippou, 2004). Davis et al. (2011) studied curricular use by focusing on PDC through an examination of how two teachers interacted with a given technology-mediated science unit. Findings indicated that one teacher made changes to the curricular recommendations consistent with reform methods and enhanced student learning, while the other teacher made changes that shifted the intent of lessons away from reformed teaching methods. The

changes teachers make should align with the goals of the curriculum for revisions to maintain consistency with the intended outcomes from a given lesson or unit (Davis et al., 2011). While Davis et al. (2011) provide a clear perspective of changes made to curriculum materials, the data for their study were collected through interviews, written narratives, self-study and email without explicit analysis of teachers' capacities during lesson planning and implementation. This work highlights the need to observe teachers during the iterative teaching cycle to clarify how their capacities are reflected differently in planning and teaching.

Pedagogical Design Capacity

In the last several years, the work on PDC has begun to take hold in mathematics and science education because of the demand to know more about how teachers use resources and make instructional decisions. Work by Brown and Edelson (2003) served as a catalyst for much of this recent work by focusing on one teacher implementing one activity; the small nature of this study called for continued work in the field. Building on this, Beyer (2009) conducted research analysing how preservice teachers developed PDC as they took part in a methods course. This initial work was later augmented with a continued focus on PDC development during teacher education (Beyer & Davis, 2012). Beyer and Davis (2012) studied preservice teachers as they analysed lesson plans as a pre-test and post-test during the semester of methods courses and completed a curriculum materials assignment. Seven participants were also interviewed; however, the study did not examine PDC during implementation, but rather focused on the preservice teachers' abilities to develop capacity related to curriculum use. In other recent work, Land (2011) focused on four expert teachers and completed a minimum of six observations per teacher participant while using video stimulated recall interviews to ask teachers retrospectively about their goals, the design of the lesson, and the observed teaching. In contrast to the work of Beyer and Davis (2012), Land (2011) methodologically focused on PDC during implementation, but did not describe how teachers' underlying capacities were reflected in different situations, such as the relationship between planning a lesson and teaching that lesson. Focusing on both lesson design and lesson implementation in the same study is important for providing a broader and more nuanced picture of teachers' PDC. This knowledge will provide a more holistic description of teachers' capacities. Therefore, understanding how the PDC of teachers shifts or remains the same at different points in the teaching cycle is important for understanding how capacity is reflected differently in planning and teaching.

Methods

A multiple-case design of case study (Yin, 2009) was implemented to provide opportunity for an in-depth study of the teachers' levels of PDC (Brown, 2009). This method permitted the use of a replication design, allowing for an in-depth examination of the lesson design process for each participant as a unique case (Yin, 2009). Due to the nature of case studies, this is a small-scale study meaning findings cannot be generalised to populations, but can add to theory or generate frameworks as a way to understand phenomenon. Likewise, it is intended that practical changes may be considered when providing professional development for mathematics teachers. The methods of the study, including data collection and analysis were framed around understanding the teachers' PDC at various points during the iterative teaching process, which distinguishes this work from other work in the field.

Participants

Four teachers, with the pseudonyms of Ms. Avila, Ms. Bodega, Ms. Carmel, and Ms. Drake, were purposely selected for participation in the study because they all taught fourth grade at a school that had met Adequate Yearly Progress (a term designated by the government based on standardised test

performance) in mathematics for the past three consecutive years. These teachers taught all subject areas in self-contained classrooms in the same school. The school was one of approximately sixty-five elementary schools grouped together in a school district in a state in the western portion of the United States of America.

Ms. Avila was in her first year teaching after recently graduating from a teacher education program. Ms. Bodega, Ms. Carmel, and Ms. Drake had 12, 15, and 17 years of teaching experiencing, respectively, with 11, 12, and 13 years at the current school. Ms. Avila had received no mathematics professional development support since being hired. Ms. Bodega, Ms. Carmel, and Ms. Drake's professional development in mathematics was limited to one day of training when the Everyday Mathematics curriculum series had been adopted by the school district seven years prior to the study; in this region it was common for the school district to mandate the curriculum to be used in the schools. Everyday Mathematics, developed by the University of Chicago, is a comprehensive commercially available curriculum for Pre-K through grade 6 students and claims to focus on the development of conceptual understanding and problem solving (Everyday Math, 2010). Three years after adopting Everyday Mathematics, the school adopted a skills-based supplemental program termed Math 4 Today, another commercially produced product, to help students prepare for high stakes assessments. Math 4 Today is a mathematics practice activity book that includes four daily problems focused on providing standardised test practice (Learning Things, 2012). The four participants typically planned their lessons in isolation. Occasionally, Ms. Carmel and Ms. Drake would discuss their plans for lessons, but this occurred informally in passing. They did not collaboratively plan similar lessons.

Data Sources and Analysis

Data sources for this study include two main components: in-depth interviews and teaching sets. The following describes the types of data and the analysis process.

In-depth interviews

In-depth interviews are well suited for case study methodology (Yin, 2009). As a result, semi-structured interviews were implemented using a protocol designed specifically for the study (Corbin & Strauss, 2007). To gain an overall understanding of each teacher's underlying capacity, the in-depth interviews lasted between 60 and 90 minutes per participant and focused on understanding how the teacher planned mathematics lessons and made decisions in the design process. These interviews were conducted before the teaching sets took place to provide an overview to the context and type of lesson design and implementation that was germane for each teacher. The interview protocol included thirty-two questions with sub questions for each question. At the conclusion of the questions, the teachers were given a prompt asking them to think aloud as they planned their next mathematics lesson. During this process, they were encouraged to follow their usual lesson plan routine and were asked to verbalise their thinking process throughout the entire lesson design process. All interviews were audio recorded and transcribed verbatim.

Initially, each in-depth interview was coded in segments, with segment length determined by shifts in the topic of conversation. Each segment that related to lesson design, curricula use, or implementation was initially coded as either offloading, adapting, or improvising based on differential degrees in distribution of responsibility for instructional design (See Table 1).

Table 1

Differential Degrees in Distribution of Responsibility for Instructional Design (Table adapted from Brown & Edelson, 2003).

	Offloading	Adapting	Improvising
General Description	“Curricular offloads are instances where teachers rely significantly on the curriculum materials to support instruction, contributing little of their own pedagogical design capacity to the implementation. Offloads are shifts of curriculum design responsibility to the materials” (p. 6)	“Curricular adaptations are instances where teachers adopt certain elements of the curriculum design, but also contribute their own design elements to the implementation. Most instances of curriculum-use involve some sort of adaptation, be it deliberate or unintentional. Adaptations are characterised by a ‘shared’ responsibility for curriculum design, distributed between the teachers and the materials” (p. 5)	“Curricular improvisations are instances where teachers pursue instructional paths of their own design. In these cases, the materials may provide a ‘seed’ idea, but the teacher contributes the bulk of the design effort required to bring the activity to fruition” (p. 7).
Curricular Reliance	Significant reliance on tasks, worksheets, and pedagogical steps from curricular materials	Moderate reliance on tasks, worksheets, and pedagogical steps from curricular materials	Little, if any, reliance on tasks, worksheets, and pedagogical steps from curricular materials
Design Responsibility	Responsibility of design is on the materials	Responsibility of design is shared between materials and the teacher	Responsibility of design is on the teacher
Instructional Path Dictation	Instructional paths are dictated by the curricular materials	Instructional paths are dictated by the teacher and the curricular materials	Instructional paths are dictated by the teacher

After each segment of a given transcript was coded with one of the three degrees of artefact appropriation, offloading, adapting, or improvising, each specific section was coded at a secondary level to determine the mediating aspects that may have influenced the teacher's underlying capacity. These themes often related to students, parents, other teachers, assessments, administrators, or the like. Figure 1 provides a specific example of coding for one segment from Ms. Drake's in-depth interview. The segment was determined to be a representation of *adapting* (coded on left) because Ms. Drake took ownership for determining the content that would be taught, based on her knowledge of standards, assessments, and the textbook series (coded on right). She selected which lessons she would include and which lessons she would skip; it is important to note that this is a small excerpt and does not include all of her thoughts about what to teach.

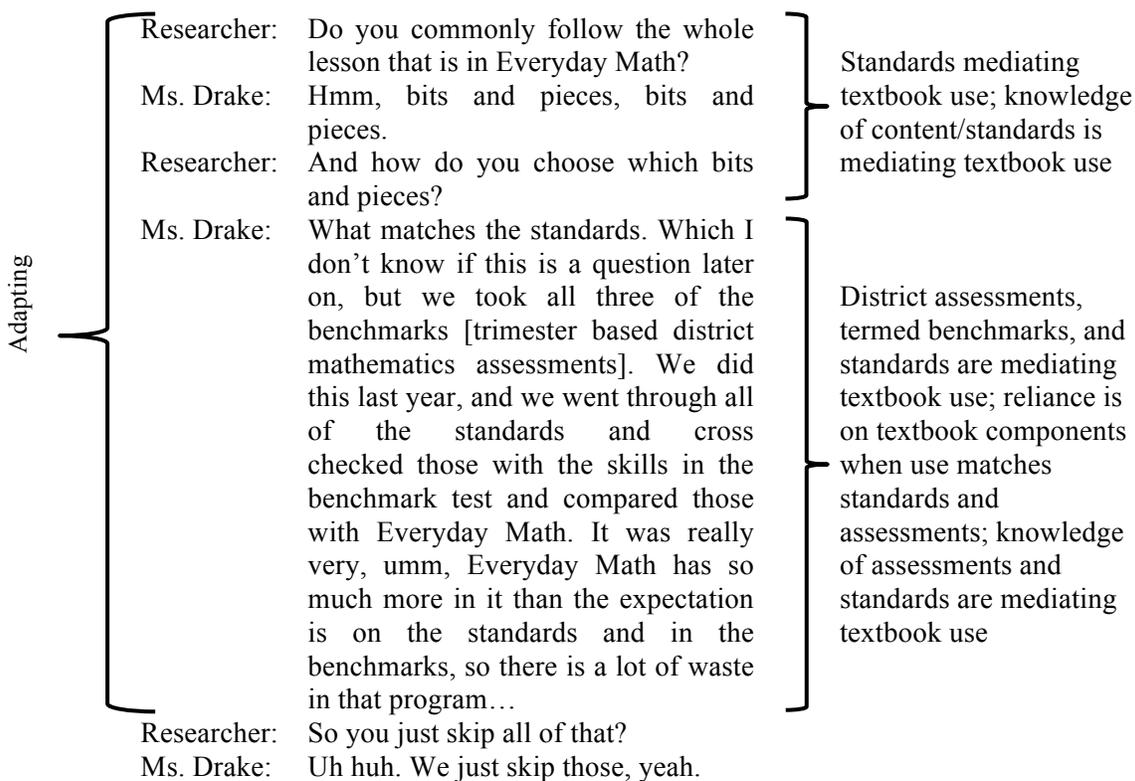


Figure 1. Example of coding with initial coding on the left (adapting) and second level coding on the right.

After each segment was coded according to differential degrees in distribution of responsibility and coded for mediating influences that provide insight with respect to the teacher's capacity, the coded interviews were reviewed by the researcher to find themes with respect to PDC and the reasons for varying reliance on curricular materials. This process was repeated for each of the four teachers.

Teaching sets

While the in-depth interviews provided holistic information about the PDC of each teacher, the teaching sets allowed for comparisons in PDC from the point of lesson design to lesson implementation. Teachers were directly observed through five consecutive teaching sets each,

which included the pre-planning process, the instruction, and any post lesson reflection, to gather information about the context and their capacity to design lessons. Teaching sets were scheduled so that all five lessons would be part of one unit on one specific mathematical topic; however, not all teachers chose to teach the same content. On each day of the teaching sets, teachers provided their daily written lesson plans and were interviewed before they taught their mathematics lesson through semi-structured interviews aimed at understanding the planned lesson. These interviews typically lasted between 10 and 20 minutes and included eight questions focused on the beginning, middle, and end of the planned lesson, the learning goals, assessment, and the relation between previous and future lessons. Following the pre interview, the daily mathematics lesson was observed and recorded through a video recorder, audio recorder, and observational field notes (Corbin & Strauss, 2007). Any mathematics artefacts used during the lesson that were not a part of the textbook series were gathered as evidence. Following the lesson, a post interview was conducted with each teacher, lasting between 10 and 20 minutes and focusing on the lesson components to expose the relation between the planned lesson and the actual instruction. This process was repeated for five consecutive days of mathematics instruction for each teacher, totalling approximately 300-450 minutes of lesson observation per participant.

All data from the teaching sets, including interview transcripts, field notes, and video transcripts were initially read in entirety. Because the intent of the research question was to understand differences in capacity when teachers were in different situations (i.e. during lesson design versus implementation), the data types were initially separated between those that pertained to lesson design (pre lesson interview and written lesson plan) and those that pertained to implementation (video recording of lesson, observational field notes, post lesson interview) for each teacher for each day, as show in Figure 2.

One Teaching Set	
Lesson Design Data Group	Lesson Implementation Data Group
Pre Lesson Interview	Video Recording of Lesson
Written Lesson Plans	Observational Field Notes
	Post Lesson Interview

Figure 2. Data from one teaching set; each of the four teachers participated in five data sets

This resulted in 40 groups of data, a lesson design group and a lesson implementation group (two groups) each day (over five days) for each participant (four teachers). Again, the analysis process in Figure 1 was used for each of these groups to describe instances of offloading, adapting, or improvising. Initially, the same analysis process used on the in-depth interviews was used for each of the data groups from the teaching sets; however, after all data relating to lesson design for a given day for a given teacher were analysed, an overall designation of offloading, adapting, or improvising was determined for that data group collectively. The same was done for the lesson implementation data. These overall designations are reported in Table 2 in the results section.

For example, on the first day of Ms. Drake’s teaching sets, the researcher conducted a pre interview and collected the written lesson plan. During data analysis, this interview contained five segments that were all coded as *improvising*. Likewise, the written plan made no mention of curricula reliance, so *improvising* was determined to be the level of PDC at the point of lesson design for Ms. Drake for that given day. During lesson implementation, the researcher observed a teacher-created lesson in which students worked in pairs to find the range of a student generated data set and a post interview was conducted. During data analysis, the field notes from the lesson noted that the teacher did not physically use any curricular materials and reported to the students that the lesson was self-generated. Analysis of the post interview data

revealed that all coded segments were examples of *improvising*. Based on the data, the post lesson data set was coded as *improvising*. Therefore, for lesson one, Ms. Drake’s PDC was coded at the level of *improvising* for both the lesson design and lesson implementation. This process of determining an overall degree of curricular reliance was conducted for each data set for each teacher.

Results

Results comparing teachers’ capacities from lesson design to lesson implementation indicate that when capacity changed, the changes were always in the direction of less curricular reliance and increased self-created lesson components. Of the 20 studied teaching sets, shifts toward improvising occurred seven times. In the remaining thirteen instances, the capacity of the teachers did not change. Of the four teachers studied, Ms. Drake’s capacity was always at the level of improvising for both design and implementation. Analysis to understand the mediating aspects responsible for the shifts toward improvising suggest that testing, whether at the state, district, or classroom level, provided the context that influenced the underlying capacity of the teachers.

To understand how the teachers’ PDC was reflected differently in planning and teaching, an overall descriptor of each teacher’s PDC at the point of lesson design and at the point of lesson implementation was determined. Table 2 includes the designated level of PDC for each teacher, for five consecutive teaching sets, once during lesson design and once during lesson implementation. The overall designation of *offloading* (O), *adapting* (A), or *improvising* (I) is provided for each teacher for each lesson.

Table 2
PDC at the Point of Lesson Design and Implementation for each Teacher for each Teaching Set

Teacher		PDC				
		Teaching Set Number				
		1	2	3	4	5
Ms. Avila	Lesson Design Data Group	<u>A</u>	I	<u>O</u>	<u>A</u>	A
Ms. Avila	Lesson Implementation Data Group	<u>I</u>	I	<u>A</u>	<u>I</u>	A
Ms. Bodega	Lesson Design Data Group	<u>O</u>	O	O	<u>A</u>	O
Ms. Bodega	Lesson Implementation Data Group	<u>A</u>	O	O	<u>I</u>	O
Ms. Carmel	Lesson Design Data Group	I	<u>A</u>	<u>A</u>	A	O
Ms. Carmel	Lesson Implementation Data Group	I	<u>I</u>	<u>I</u>	A	O
Ms. Drake	Lesson Design Data Group	I	I	I	I	I
Ms. Drake	Lesson Implementation Data Group	I	I	I	I	I

In Table 2, bold and underlined letters indicate a capacity shift on the continuum toward improvising from lesson design to lesson implementation. The following describes the teachers’ capacities during lesson design and implementation as related to Table 2.

Ms. Avila

Ms. Avila’s planning process involved consideration of what students knew and understood, pacing guides, and the district provided materials. To plan, she sat down with these materials daily and considered what and how she would teach the following day. Ms. Avila’s PDC was reflected differently from the point of lesson design through lesson implementation during

lesson one, lesson three, and lesson four. Ms. Avila's first lesson focused on preparing students for an upcoming district assessment in mathematics. To prepare students, her plan included the following:

Ms. Avila: Today they are just doing their Day 3 in their [Math 4 Today] packet. Then, we will go over it together on the overhead. Then, they will put that away and we are going to go over some practice problems to kind of stimulate problems that they will see on the district test, just to familiarise them with the language, and what those things will look like, so we are venturing away from Everyday Mathematics today, just to get a little more thorough practice.

Ms. Avila had written the practice problems for the test on her own, but included the Math 4 Today as a curricular component in the lesson, resulting in an overall lesson design designation of *adapting*.

As Ms. Avila began the lesson, students worked on their daily practice problems and she corrected the problems with the students using an overhead projector. After correcting the problems, the following conversation took place regarding question 2, which showed a square pyramid and asked, "How many faces does this figure have?"

Sam: I have a question about the second box (question regarding square pyramid). It looks like a box.
Ms. Avila: Oh, so you didn't see it as a pyramid? You saw it as a?
Student: I didn't see it as the pyramid.
Students: I didn't see it...
Ms. Avila: So, so hold on guys (attempts to quiet multiple students). So, Sam, when you looked at this were you thinking you saw more of a cube than a pyramid?
Sam: Yes.
Ms. Avila: So, you saw sides like this (makes cube gesture with her hands)? So, Sam, when you looked at this, on top, is that what you were thinking?
Students: Yeah.

Ms. Avila questioned Sam to clarify his thinking and realised that he was unable to visualise the three dimensional aspects of the square pyramid based on the drawing (see Figure 3).

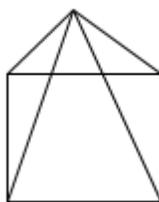


Figure 3. Square pyramid drawn on the worksheet for question 2 in Math 4 Today

As Ms. Avila worked to clarify Sam's understanding, it became apparent that many students in the classroom were struggling with the same problem. At that point, Ms. Avila made a decision to deviate from her planned lesson of having students work on test practice problems. She moved to her desk, took out construction paper and began creating a model of a square pyramid for students; thus, shifting away from moderate reliance on worksheets from Math 4 Today to teach a mini-lesson on faces of three-dimensional figures in which she assumed responsibility for design and dictated her own instructional path. This move to disregard her plan and textbook use to implement a new activity to help students understand geometric figures resulted in a PDC shift from *adapting* during the planned lesson to *improvisation* during implementation. Ms. Avila spent the remainder of the mathematics time helping students understand geometric vocabulary, such as *face*, on three-dimensional figures. Her purpose for

making this change was to help students prepare for the upcoming district assessment; she considered the content about the square pyramid to be important for their success on the test.

For Ms. Avila's third lesson, she planned to have her students redo a worksheet she had given them previously in which they struggled with the mathematics. Based on the lesson design data group for teaching set three, Ms. Avila's capacity was at the level of *offloading* because she planned significant reliance on worksheets with instructional paths dictated by curricular materials. As Ms. Avila taught the lesson, she decided it would be helpful to spend time teaching some of the concepts that appeared on the worksheet as opposed to having students correct each worksheet problem. She deviated from her plan for instruction and included a fifteen-minute component to clarify student understanding. When asked about the shift, she indicated, "I think it helped to just kind of clear up some, you know, just confusion or just to kind of straighten things out for some of them." This shift from dependence on the worksheet during the plan to the incorporation of her own mini-lesson for concept review, resulted in a shift from *offloading* while planning to *adapting*, during implementation.

In the aforementioned instances, and with the fourth teaching set, Ms. Avila's PDC was the result of realisation that her students lacked understanding of the content she wanted them to know for an upcoming assessment. She made changes to incorporate her own methods and mini-lessons to help ensure students understood the relevant concepts of the lessons. As she made these changes, she assumed additional curricular reliance and increased design responsibility.

Ms. Bodega

Ms. Bodega's planning process involved mapping lessons from a non-district adopted curriculum to the calendar. To plan, she considered one lesson in the curriculum to be the equivalent to the lesson content for one day. As Ms. Bodega prepared to teach, she typically planned lessons with significant reliance on curricula. In an effort to improve the procedural proficiency of her students, Ms. Bodega disregarded the district adopted Everyday Mathematics textbook series and began daily implementation of Houghton Mifflin textbook materials. Due to her heavy reliance on textbooks while planning, Ms. Bodega's first, second, third, and fifth lesson were all designated at the level of *offloading* with design responsibility placed on the curricular materials. Her first lesson changed to *adapting* while teaching and her fourth lesson started at *adapting* and shifted to *improvising*. Closer examination of these two shifts reveals that Ms. Bodega was highly dependent on using instructional materials, but occasionally included other procedural methods in her lessons that she thought would benefit students.

When asked about her first lesson, Ms. Bodega commented, "We start off math every day with Math 4 Today, so we will warm up with that and they do their times test and then we get into the actual lesson and we will talk about what an improper fraction is and why we can't leave it that way and what we need to do to make it a mixed number." She then planned for her students to complete a worksheet on changing improper fractions into mixed numbers. As Ms. Bodega implemented the lesson she began doubting the usefulness of providing visual models of changing improper fractions into decimals. She deviated from her plan to illustrate visual models of fractions on the board, resulting in shared instructional paths between the teacher and the resources. When asked about this, Ms. Bodega questioned her process of using visuals, "I like to give them visual cues, however, sometimes I think they try to fall back on that too much and it ends up, and I explain that to them, that they can't rely on drawing pictures all of the time because it would just take them too long." In this case, Ms. Bodega's PDC shifted to *adapting* during implementation because she inserted problems in her lesson that were not from the textbook to help students understand the concept of changing improper fractions to mixed numbers.

Following the aforementioned first lesson, the only other teaching set that revealed a shift in PDC for Ms. Bodega was her fourth lesson, which was originally designed to be *adapting* and was implemented as *improvising*. The fourth lesson was designed as test preparation, so that students would be able to successfully complete a Houghton Mifflin created test the following day. As a result, Ms. Bodega decided that students would start class as usual with Math 4

Today and timed facts test, but that she would deviate from the text series to provide students with practice problems. This appeared routine for Ms. Bodega as she indicated, “Whenever we have a review, I have them take out their planners and I tell them exactly what they will need to know, what is going to be on the test, and what they need to study and they write that down in their planners.” As Ms. Bodega taught the lesson, she deviated from her planned practice problems when students were struggling with simplifying fractions and *improvised* to give “them some clues as to what they could be looking for in terms of knowing whether or not a fraction needs to be reduced. For example, the numerator is one away from the denominator.” Her intent with this deviation was to prepare students for an in-class assessment the following day. Again, similar to Ms. Avila, Ms. Bodega’s PDC shifted to assume increased design responsibility during the lesson in an attempt to prepare students for assessments.

Ms. Carmel

Ms. Carmel’s planning process involved reflecting on how testing content was implemented in previous years, searching through materials to address that content, and then planning for upcoming lessons. To plan, she thought about what students would need to know for forthcoming assessments, and coordinated lessons from a variety of resources, including her own ideas, to plan lessons. Similar to Ms. Bodega, Ms. Carmel’s capacity was reflected differently from design to implementation in two of the five observed teaching sets. Ms. Carmel’s PDC during the planning stage for the first and third teaching set were both *adapting* and shifted during implementation to *improvising*. During the second teaching set, Ms. Carmel planned to begin the lesson with some review practice problems and then work on preparing students for a constructed response test question on perimeters that would be on an upcoming district assessment. As Ms. Carmel taught the lesson, she gave the students a self-created challenge problem that had not been planned, to increase interest in the content. In doing so, she assumed design responsibility of the lesson.

Ms. Carmel’s PDC for the third teaching set was also classified as *adapting* in the planning stage and shifted to *improvising* during implementation. Initially, Ms. Carmel had planned the following, indicating moderate curricula reliance:

We are going to bring in the rulers, so again what we will do is we will do practice problems given a total perimeter. Can you create a polygon with that perimeter? I will also have them do that exact same thing, but I will bring in rulers, so they can get themselves familiar with drawing an accurate polygon with the ruler...Then, for practice in measuring, we will do a page out of the Mailbox Magazine that has, where they have to use a ruler to measure the sides of all of the polygons and then calculate the perimeter.

The combination of self-created problems and the worksheet from the magazine resulted in a planned lesson that would be *adapted* from the curriculum. When Ms. Carmel taught the lesson, the students were able to complete the given problems with ease, so “I threw in, they were finding the perimeter of, the shape on the page. And so then, we extended it out by having them find the five objects in the room. And they had to use the ruler and measure that up.” Including an unplanned self-created activity resulted in *improvising* because Ms. Carmel dictated the instructional path without curricular reliance. She made the change to ensure that students would know the necessary material for assessments. Her plans and implementation with respect to PDC for the other three lessons did not change. As with Ms. Avila and Ms. Bodega, Ms. Carmel’s PDC shifted due to her focus on summative test preparation for students.

Ms. Drake

As Ms. Drake’s planned, she considered standards that needed to be taught for upcoming assessments and thought about how she had taught similar content in the past. To plan, she devised lessons based on her own ideas of what should be included in a lesson on particular content. In contrast to the three aforementioned teachers, Ms. Drake’s PDC remained constant throughout all five teaching sets. In the case of Ms. Drake, her initial PDC based on the lesson design data group was at the point of *improvising* for all five lessons, thus indicating continual

minimal curricular reliance with self-determined instructional paths. For example, for lesson one, Ms. Drake said, "The goal today is graphing and the landmarks and then we will continue tomorrow with more area and perimeter." When asked, "Okay, and did you get this lesson from somewhere?" Ms. Drake commented, "No, I invented this one." After the lesson, she was asked, "How closely did you follow your plan?" and she remarked, "It was to the T!" This example provides insight to the underlying capacity that was reflected as Ms. Drake designed lessons and implemented her plans in the classroom. The next day, for teaching set two, Ms. Drake's PDC was similar during the design stage.

Ms. Drake: We are measuring. Just to show them the units of measure.

Researcher: That sounds good. And where did you get this lesson?

Ms. Drake: Umm, again, I just self-created. I just yeah, I was just thinking about where we went with the irregular shape and then moving toward the [area] formula.

Ms. Drake's written lesson plans provided evidence for her capacity of improvising; her written lesson plans were very brief and made no mention of curricular material reliance (see Figure 4).

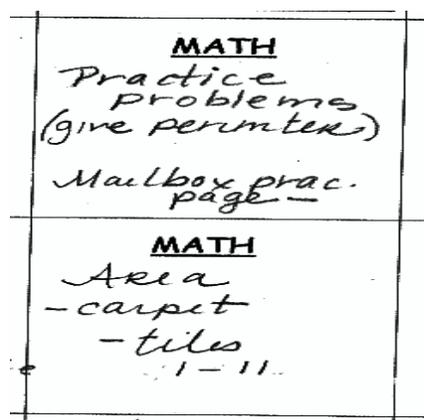


Figure 4. One day of written lesson plans for Ms. Drake.

When asked about the brevity of her written plans, Ms. Drake indicated that she didn't have to write so much...because really it is in my head." This pattern of self-created lessons and implementation that followed the self-created plan was routine for Ms. Drake. To further understand Ms. Drake's reasoning for her decisions, she was asked, "How do you determine the exact content of the lesson you will teach?" Her response indicated that her decisions were assessment driven. She said, "I try to follow the standards....because they follow the test that the kids take once every trimester. So I do try to stay up to whatever the standards are in the order they are presented in those tests." Each day Ms. Drake planned the lesson on her own, based on the previous day's lesson, in combination with what she thought students needed to know for upcoming assessments. She then implemented each observed lesson without the use of textbooks, demonstrating her capacity to improvise.

Discussion, Implications, and Future Research

The purpose of this research was to understand how teachers' underlying capacities were reflected differently in planning and teaching, specifically from the time of lesson design to lesson implementation. This is important for knowing the types of changes teachers are making with respect to curricular material use to know how to better support teachers as they plan and implement lessons.

Pedagogical Design Capacity Explored

As the teachers designed and implemented lessons, all four referenced testing as a mediating influence that altered their use of curricular artefacts. Specifically, as the teachers further considered testing, they relied on the district guidelines about what would be tested and disregarded components of the textbook they did not consider applicable for test preparation. Examples of this type of capacity were evident in both the lesson design and implementation data. As the teachers were planning lessons, they were cognizant of the testing requirements at the classroom, district, and state level and determined textbook reliance in conjunction with what students needed to know for assessments. If they considered a self-created lesson to be more meaningful for student test preparation, then they designed their own lessons. Likewise, in some instances the teachers digressed from textbook reliance to include self-created lesson components if students were confused or did not seem to understand the intended outcomes. This approach was supported in the educational context where the teachers worked. Recall that the administrators had purchased supplementary curriculum, *Math 4 Today*, to aid teachers in preparing students for assessments.

Teachers' PDC was mediated by what they perceived to be important for students to know for assessments, which influenced how they manipulated curricula as artefacts (Shield & Dole, 2012; Wartofsky, 1973) and how they perceived their relationship with curricula (Remillard, 2005). The teachers' decisions were each mediated by their perception of the benefit of curricula use for test preparation; at the same time, their perception of the assessments their students would take influenced how they perceived the available curricular materials (Amador & Lamberg, 2013). In these cases, they perceived the curricula as an artefact they could mobilise for instruction *if* the textbook would accurately prepare students for upcoming assessments. As the teachers interacted with the materials in this way, their reliance on curricular materials, including textbooks decreased and the incidence of self-created lessons increased. Often, this shift happened in the moment of implementation because of a decision about how to best prepare students for assessments.

When teachers make this shift toward improvisation (Brown, 2009) it is possible that they may make changes that ignore the intent of the textbook designer (Davis et al., 2011). When this happens, the teacher begins to become the curricular designer and issues of scope and sequence may pervade. In contrast, when teachers rely heavily on textbook materials and maintain fidelity to a specific curricular series, they may lose focus of the standards and actual content students need to know in mathematics. As a result, to understand these shifts in the underlying capacity of teachers, it is essential to realise that a shift toward improvisation does not imply effective teaching. Instead, it is important to understand the positive and negatives of the extremes of Brown's (2009) PDC continuum and the roles of offloading, improvising, and adapting.

Considering the variance with the continuum, Ms. Drake presents a unique case apart from the other cases. She indicated that she self-created her lessons and her implementation followed this logic. What is not apparent is whether or not Ms. Drake's deviation from materials was an example of someone who planned diligently and did not use resources or if she spent very little time planning and created lessons as she went along with her teaching. Based on the interview data, Ms. Drake mentions several resources, such as *Everyday Mathematics* and *Mailbox Magazine*, but it is important to realise that her improvisation of every lesson does not imply that every lesson was effective. Likewise, this case is not to argue that offloading is always effective or to evaluate the effectiveness of teaching; instead, the data provide understanding for how teachers plan and implement lessons. In this case, data revealed that Ms. Drake improvises, according to the framework, and relies minimally, if at all, on curricular materials.

Supporting Teachers

The findings of this work highlight four teachers' attempts to provide effective mathematical instruction for their students. All four teachers commented that they were making pedagogical decisions based on what they consider the most beneficial for students; in many

instances they made a direct connection to what would best prepare students for assessments. These findings emphasise the need to support teachers in knowing how to best provide learning opportunities for students, so students will meet the teachers' goals of doing well on assessments. At times, these teachers were so focused on making decisions because of assessments that they reduced their focus on how students were learning from day to day. This was especially true with Ms. Brown who taught the next lesson she had planned irrespective of how the previous lesson had gone and how she perceived learning in the previous lesson. As the teachers adapted and improvised lessons, they often veered away from curricular recommendations. For example, Ms. Avila adapted her lessons and improvised to the point that over the course of the five teaching sets she was multiple lessons behind. Over time, if this pattern repeats, Ms. Avila would eventually be faced with decisions about curricular material to teach and what to omit. As a result, it is important that teachers gain understanding about how to make these decisions while being cognizant of the mathematical learning goals for their students. Essentially, this study highlights the differences occurring in classrooms with curriculum use and the relationships teachers had with materials from the point of planning through implementation (Remillard, 2005). This underscores that even the most thought out plans do not always transpire, which results in further adjustments to the mathematical scope and sequence of future lessons. These understandings provide information about the teachers' PDC and provide insight about the extent to which they are relying on curricular materials.

Study Approach

This work builds upon previous research (Brown & Edelson, 2003; Brown, 2009; Davis et al., 2011; Land, 2011) by utilising a methodological approach that focused on PDC at various points in the teaching cycle—both during planning and teaching. Beyer & Davis (2012) examined preservice teachers' abilities to develop PDC and Land (2011) studied the PDC of practicing teachers as she observed them teaching, but neither study provided insight into the shifts in PDC that may be the result of mediating aspects of teaching. The present study extends previous work by focusing on PDC at different points in the teaching cycle, which provides a more holistic understanding of teachers' PDC, and provides support for why these changes may have occurred. This methodological approach could be replicated with teachers in other settings to further understand how PDC shifts from planning to teaching, which would provide even more insight about how to support teachers as they implement lessons.

Limitations and Future Research

While this work highlights the practices of four teachers, it is important to realise the findings cannot be generalised to all teachers, but do augment the knowledge base around PDC and provide a basis for continued studies focused on PDC. Further research should focus on the role of the institutional context as related to PDC. Perhaps the context of the school where these four teachers worked influenced their PDC because administrators focused heavily on assessment results. Thus, understanding how teachers' capacities were reflected differently in planning and teaching provides insight for knowing how to support teachers as they work with curriculum materials. Additionally, knowing about the relationship between improvising and student understanding could provide useful information for lesson design. Based on these findings, it would be important to support these teachers on how they make decisions about curricular materials to develop student understanding. While a portion of these results provide scholarly evidence for what can sometimes be taken-for-granted assumptions about the nature of instruction, this work provides information to the field of educational research beyond that which is readily known about teachers' capacities during the process of designing and implementing lessons.

References

- Amador, J., & Lamberg, T. (2013). Learning trajectories, lesson planning, affordances, and constraints in the design and enactment of mathematics teaching. *Mathematical Thinking and Learning, 15*, 146-170.
- Ben-Peretz, M. (1990). The teacher-curriculum encounter: *Freeing teachers from the tyranny of texts*. Albany: State University of New York Press.
- Beyer, C., & Davis, E. (2012). Learning to critique and adapt science curriculum materials: Examining the development of preservice elementary teachers' pedagogical content knowledge. *Science Education, 96*, 130-157.
- Brown, M. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. Herbel-Eisenmann, & G. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17-36). New York: Routledge.
- Brown, M., & Edelson, D. (2003). Teaching as design: Can we better understand the ways in which teachers use materials so we can better design materials to support changes in practice? *Research Report, Center for Learning Technologies in Urban Schools* (Northwestern University). <http://www.letus.org/papers.htm>
- Chval, K., Reys, R., Reys, B., Tarr, J., & Chavez, O. (2006). Pressures to improve student performance: A context that both urges and impedes school-based research. *Journal for Research in Mathematics Education, 37*, 158-166.
- Choppin, J. (2011). Learned adaptations: Teachers' understanding and use of curriculum resources. *Journal of Mathematics Teacher Education, 14*, 331-353.
- Christou, C., Eliophotou-Menon, & Philippou, G. (2004). Teachers' concerns regarding the adoption of a new mathematics curriculum: An application of CBAM. *Educational Studies in Mathematics, 57*, 157-176.
- Clandinin, D. J., & Connelly, F. M. (1991). Teacher as curriculum maker. In P. Jackson (Ed.), *Handbook of research on curriculum* (pp. 363-401). New York: Macmillan.
- Cobb, P., McClain, K., Lamberg, T., & Dean, C. (2003). Situating teachers' instructional practices in the institutional setting of the school and school district. *Educational Researcher, 32*, 13-24.
- Corbin, J., & Strauss, A. (2007). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.
- Davis, E. A., Beyer, C., Forbes, C. T., & Stevens, S. (2011). Understanding pedagogical design capacity through teachers' narratives. *Teaching and Teacher Education, 27*, 797-810.
- Everyday Mathematics Resource and Information Center. (2010). Retrieved June, 2010 from <http://everydaymath.uchicago.edu/>.
- Freeman, D., & Porter, A. (1989). Do textbooks dictate the content of mathematics instruction in elementary schools? *American Educational Research Journal, 26*, 403-421.
- Lamb, J. (2010). Leading mathematics reform and the lost opportunity. *Mathematics Teacher Education and Development, 12*, 36-42.
- Land, T. (2011). Pedagogical design capacity for teaching elementary mathematics: *A cross-case analysis of four teachers*. Graduate Theses and Dissertations. Paper 12120. <http://lib.dr.iastate.edu/etd/12120>
- Learning Things (2012). Retrieved from <http://www.learningthings.com/itemdesc.asp?ic=CD-0768232023>.
- McClain, K., & Cobb, P. (2004). The critical role of institutional context in teacher development. *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education, 3*, 281-288.
- Pea, R. (1985). Beyond amplification: Using the computer to reorganize mental functioning. *Educational Psychologist, 20*, 167-182.
- Remillard, J. (1992). Teaching mathematics for understanding: A fifth-grade teacher's interpretation of policy. *The Elementary School Journal, 9*, 189-193.
- Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*, 211-246.
- Sherin, M. G., & Drake, C. (2009). Curriculum strategy framework: Investigating patterns in teachers' use of a reform-based elementary mathematics curriculum. *Journal of Curriculum Studies, 41*, 467-500.
- Shield, M., & Dole, S. (2012). Assessing the potential of mathematics textbooks to promote deep learning. *Educational Studies in Mathematics, 2*, 183-199.
- Stein, M. K., & Kaufman, J. H. (2010). Selecting and supporting mathematics curricula at scale. *American Educational Research Journal, 47*, 663-693.
- Tarr, J. E., Reys, R. E., Reys, B. J., Chavez, O., Shih, J., & Osterlind, S. J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education, 39*, 247-280.
- Wartofsky, M. W. (1973). Perception, representation, and the forms of action: Towards a historical epistemology. In M. Wartofsky (Ed.) *Models: Representation and the Scientific Understanding*. Dordrecht: Reidel.

Wertsch, J. (1998). *Mind as action*. New York: Oxford University Press.
Wiggins, G., & McTighe, J. (2011). *The understanding by design guide to creating high-quality units*. Alexandria, VA: ASCD.
Yin, R. K. (2009). *Case study research: Design and methods* (4th ed). Los Angeles: Sage

Author

Julie M. Amador
University of Idaho
1031 North Academic Way
Coeur d'Alene, Idaho, United States of America
jamador@uidaho.edu