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Demands, Tensions, and Resources when Implementing Ambitious Mathematics[1]

Jeffrey Choppin
University of Rochester
Christine Green
State University of New York at Geneseo
&
William Zahner
San Diego State University
United States

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Abstract: In this article, we explore demands and tensions involved when schools implement ambitious mathematics teaching (AMT). Following a description of a framework that distinguishes between internal and external demands, we characterize the tension between these in terms of alignment, balance, and buffering, which collectively speak to coherence. We then describe AMT and how it represents a departure from

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traditional mathematics instruction found in most countries. We applied the framework to an illustrative case and found that while the school devoted considerable resources to reforming mathematics teaching and learning, challenges persisted. These challenges include ongoing language and participatory demands for students and, for teachers, balancing the demands of implementing AMT with a range of other initiatives. The framework provides a means of exploring the full range of demands associated with ambitious instructional reforms, how these demands are mitigated or exacerbated, and the kinds of resources necessary to sustain AMT.
Keywords: ambitious mathematics teaching; external demands; internal demands; policy alignment; instructional reform

Demandas, tensiónes, y recursos cuando se implementa matemáticas ambiciosas
Resumen: Exploramos las demandas y tensiones involucradas cuando las escuelas implementan "Enseñanza Ambiciosa de las Matemáticas" (*Ambitious Mathematics Teaching* [AMT]). Describimos un marco que distingue entre demandas internas y externas; caracterizamos la tensión entre estos en términos de alineación, equilibrio y amortiguación, que en conjunto hablan de coherencia. Describimos la AMT y cómo representa una desviación de la enseñanza de matemáticas convencional que se encuentra en la mayoría de otros países. Aplicamos el marco a un caso ilustrativo y descubrimos que, aunque la escuela dedicó recursos considerables para reformar la enseñanza y el aprendizaje de las matemáticas, los desafíos persisten. Estos desafíos incluyen demandas continuas de lenguaje y participación para los estudiantes y, para los maestros, equilibrar las demandas de implementar AMT con una variedad de otras iniciativas. El marco proporciona un medio para explorar el rango completo de demandas asociadas con reformas educativas ambiciosas, cómo se mitigan o exacerban estas demandas y los tipos de recursos necesarios para sostener la AMT.
Palabras-clave: enseñanza ambiciosa de las matemáticas; demandas externas; demandas internas; alineamiento político; reforma instruccional

Demandas, tensões e recursos na implementação da matemática ambiciosa
Resumo: Exploramos as demandas e tensões envolvidas quando as escolas implementam o "Ensino Ambicioso de Matemática" (*Ambitious Mathematics Teaching* [AMT]). Descrevemos uma estrutura que distingue entre demandas internas e externas; caracterizamos a tensão entre estes em termos de alinhamento, equilíbrio e amortecimento, que juntos falam de coerência. Descrevemos o AMT e como ele representa um afastamento do ensino convencional de matemática encontrado na maioria dos outros países. Aplicámos o quadro a um caso ilustrativo e descobrimos que, embora a escola tenha dedicado recursos consideráveis à reforma do ensino e da aprendizagem da matemática, os desafios permanecem. Estes desafios incluem exigências contínuas de linguagem e envolvimento para os alunos e, para os professores, equilibrar as exigências da implementação da AMT com uma variedade de outras iniciativas. O quadro proporciona um meio para explorar toda a gama de exigências associadas a reformas educativas ambiciosas, como essas exigências são mitigadas ou exacerbadas e os tipos de recursos necessários para sustentar a AMT.
Palavras-chave: ensino ambicioso de matemática; demandas externas; demandas internas; alinhamento político; reforma instrucional

Demands, Tensions, and Resources when Implementing Ambitious Mathematics

There is a history of ambitious reform efforts in mathematics education that have faltered or faded (Nasir et al., 2014; Schoenfeld, 2004; Wilson, 2003). A prominent case from the mathematics education literature in the US is Railside High School (Nasir et al., 2014), which was viewed as an exemplary case of an ambitious instructional mathematics program serving a racially and ethnically diverse student population (e.g., Boaler & Staples, 2008). Ultimately, however, the effort collapsed when the mathematics teachers at Railside were overwhelmed by the demands of sustaining ambitious instruction in a high-stakes accountability context (Louie & Nasir, 2014). Two implications arise from this example. First, ambitious instructional mathematics reforms entail many demands. Second, if there are not supportive policies and resources aligned with the reforms, then the reforms falter. The framework we outline in this paper conceptualizes the demands related to AMT, how those demands may be in tension with the demands of other initiatives, and the conditions that might sustain implementations of AMT.

Concepts and Assumptions Related to Ambitious Mathematics Teaching

The reform we are most interested in is the constellation of practices referred to as ambitious mathematics teaching (cf., Lampert et al., 2010). The goal of AMT is that teachers engage students in mathematical activities that involve mathematical concepts and participation structures and pedagogies and position students as intellectual contributors (Lampert et al., 2010; Singer-Gabella et al., 2016). AMT departs from teacher-centered mathematics classroom practices. Consequently, we operate under the assumption that AMT requires most practitioners to shift their perspectives, knowledge, and practices. A corollary of this assumption is that practitioners need to develop new capacities, which requires considerable effort and resources. If ambitious reforms impose demands that initially outstrip the capabilities of those charged with implementation, there is a risk that those people will be viewed as incompetent. This potentially leads to non-compliance and, ultimately, failure (Cohen et al., 2007).

Study Context

We situated our study in a school that had implemented a mathematics program aligned with AMT for more than five years. The John Lewis School is located in the Fullerton City School District in the northeastern part of the United States and serves approximately 1,000 students in Grades 6-12. Demographically, 83% of the students qualified for free-and-reduced lunch, more than 80% of the students were identified as Black or Latinx, and high numbers of students were labeled as Limited English Proficient and as Students with Disabilities. In 2015, the City of Fullerton was ranked number one in child poverty and concentrated poverty in the United States for similar sized cities (Doherty, 2015).

The implementation of AMT at John Lewis was part of a school-wide transformation. The John Lewis School historically faced so many challenges that the state threatened to shut it down in 2014: low performance on state tests, high suspension rates, low attendance rates. At the encouragement of state educational officials, the Fullerton City School District Board of Education asked the University of Landover in 2014 to become the Educational Partnership Organization (EPO) for the John Lewis School. The goal of the EPO was "to transform the educational infrastructure and culture of underachievement of this school with an explicit focus on equity"

(Larson et al, 2021, p. 179). The EPO instituted a set of comprehensive reforms, including those pertaining to the mathematics program. As a result of the partnership, prior to the disruptions induced by COVID, the school had seen considerable increases on state assessments, including on the Algebra I Regents exam, Geometry Regents exam, and Algebra II Regents exam.

The Mathematics Program at John Lewis

As part of the EPO effort, the University of Landover and its school of education worked with John Lewis educators to design and implement a mathematics program. This effort included consultants (henceforth termed external consultants) from the school of education who supported the development and implementation of the mathematics program through coaching and professional development activities. Two of the authors on this paper worked at the University of Landover and were part of a research project that examined the mathematics program in partnership with the third author. None of the authors were external consultants to the EPO.

Our study of the mathematics program took place more than five years after the EPO launched and coincided with the advent of the COVID pandemic. The school was divided into a Middle School and High School, each of which occupied a separate wing of the building. The school had 20 mathematics teachers (12 of whom participated in the study, including those who served as teacher leaders). At both the Middle School and High School, one of those teachers also served as a teacher leader. Building administrators who supervised the math department also participated in the study.

The mathematics program was developed to be inquiry-based and focused on equity. Lester (a pseudonym, as are all the names, including the school), an external consultant who facilitated curriculum development at the EPO, explained that the EPO wanted “an inquiry-based approach to doing math and getting students to be the ones who are doing the thinking and making the connections.” She further explained the curricular philosophy at the EPO:

> [It’s] connected to equity issues, issues of equity and access. The more we limit mathematics to one way of doing something and that you’re not necessarily thinking about it but you’re expected to regurgitate things, mathematics [becomes] a gatekeeper. As opposed to supporting kids in robust thinking, bringing in their experiences and opinions and ways of thinking and ways of doing, again, to support equity issues, access issues.

These principles informed the adoption of the curriculum programs used at the EPO, described below.

Curriculum Materials Adopted by the EPO

The Lower School (Grades 6-8) adopted Connected Mathematics Program 3 (CMP3) (Lappan et al., 2014) and the Upper School (Grades 9-12) initially adopted Meaningful Math (Fendel et al., 2014) and then CORE Plus (Hirsch et at., 2015). Analyses of tasks in these materials show that the tasks elicit students’ thinking and do not initially model an approach to solve the task (Choppin et al., 2022); these characteristics provide opportunities for productive struggle (Munter et al., 2015). Furthermore, the materials emphasize connections between topics and between multiple representations in ways that traditional materials do not (Choppin et al., 2022). The teacher resources in both programs emphasize that students should collaboratively solve problems and share their thinking.

The Role of Understanding by Design (UbD) in the Curriculum Development Process

The mathematics department, consistent with other subject areas, at John Lewis was tasked with using the UbD process (Wiggins & McTighe, 2005) to develop their curriculum. The UbD framework begins by focusing on the end goals and then works backward to develop instructional content. The UbD process involves multiple stages, beginning with articulating key understandings and essential questions. This leads to the second stage, which is the development of assessments used to provide evidence that the students are meeting the Stage One goals. In the third stage, educators develop lessons that address the goals and are aligned with the assessments. UbD is an intensive, long-term process that has so far spanned seven years at the EPO. We provide more details below about how the mathematics department implemented UbD, and how this initiative impacted the implementation of AMT.

Development of the Conceptual Framework and Key Terms

As part of the conception of the study and before we began our data collection, we developed a framework to guide our work. Based on insights from the literature on ambitious reforms (e.g., Cohen et al., 2007; Louie & Nasir, 2014), we conjectured that AMT required demands beyond those entailed in traditional mathematics instruction and that resources needed to be made available to address those demands or AMT would fail to take hold. We defined a demand as a requirement for material or human resources that, if left unmet, will impede an instructional reform. Resources include materials (textbooks, infrastructure, technology), social resources (skills, knowledge, sensitivity), instructional practices (group-worthy tasks, structuring interactions), and organizational routines (decision making protocols, communication protocols, protocols for gathering data).

We further conjectured a multi-layer nested arrangement of demand-resource pairings, in which a demand for one agent in the system (e.g., the demand for a student to participate in a classroom mathematical discussion) induces the need for the provision of resources by another agent (e.g., the teacher must provide resources by creating a classroom where students feel safe participating in mathematical discussions). We termed demands related to AMT as internal demands, which begin with students and emanate outward to teachers, instructional leaders, and administrators. We reviewed literature to flesh out the demands associated with AMT, and arrived at three types of demands: knowledge, perspective, and practice demands.

We shared iterations of the conceptual framework during spring 2022 with our project advisory board that consisted of educators with decades of cumulative experience conducting or researching ambitious mathematics teaching reform efforts in high need contexts. The advisory board, in addition to personnel from the research site, emphasized the presence of other demands on schools that might influence teachers' attempts to implement AMT. This led us to incorporate external demands, which we characterize as demands that originate from outside the classroom and push inward toward the classroom. External demands flow from educational discourses and related policies voiced by stakeholders at the school, regional, and national levels. These discourses entail commitments, obligations, and perspectives that are historical, political, and ideological and that may differ from those related to AMT (Wilson, 2003).

To conceptualize the tensions between internal and external demands, we included the notions of alignment, balance, coherence, and buffering in the framework. We then turned back to the literature to flesh out these notions. After finalizing the framework, we used it to create the analytic framework summarized in Table 1. We then applied the analytic framework to data from the research site to create an illustrative case study (cf. Kazemi et al., 2022), of AMT reform at John Lewis, which we explain in more detail below.

Internal Demands Related to AMT

We identified three types of demands: knowledge demands, perspective demands, and practice demands. There is considerable overlap between demands associated with organizational levels above the student, an interconnectedness that led us to combine the discussion for these levels. We start by explaining the demands identified in the literature faced by students in ambitious mathematics programs. These demands, and the resources necessary to address them, subsequently frame the demands placed upon teachers, which in turn frame demands placed upon instructional leaders and administrators.

Demands Placed on Students

The literature in mathematics education has identified a set of interrelated demands on students that result from the implementation of ambitious mathematics programs, including linguistic demands, cognitive demands, and participatory demands, explained below.

Knowledge Demands: Linguistic and Cognitive Demands

One of the defining characteristics of AMT is bringing classroom mathematical practices closer to disciplinary practices (Lampert et al., 2013). The discipline of mathematics involves unique linguistic demands such as the multisemiotic nature of mathematical texts, the nominalization of verbs that result in dense phrases, and the precise meanings of conjunctions and logical relationships in mathematics discourse (Schleppegrell, 2007). These features of discourse make it challenging for students to move from informal ways of communicating to the more formal and precise uses of the mathematics register expected to be used in mathematics classrooms (Pimm, 1987). The linguistic demands on students may be magnified in ambitious mathematics programs, which require the "orchestration of mathematical discussions that support learners to use mathematical language to express their thoughts clearly and assist with developing mathematical reasoning" (Averill et al., 2016, p. 488). Students from low socioeconomic status backgrounds and multilingual students who are learning the language of schooling are especially likely to be affected by the linguistic and discourse demands of AMT (Lubienski, 2000; Moschkovich, 2013; Zahner et al., 2021).

Ambitious mathematics programs entail increased cognitive demands related to tasks. Tasks associated with AMT are non-routine, focus on important mathematical concepts, and have multiple solution approaches (Boston & Candela, 2018; Jackson et al., 2017). The lack of a specified approach for solving these non-routine tasks induces the higher cognitive processes in students (Doyle, 1988) by requiring students to exercise flexibility (Renkl & Atkinson, 2003). As students encounter more complicated and open-ended tasks, the cognitive load, or the effort required to manage a problem or situation, increases (DeLeeuw & Mayer, 2008).

Perspective Demands: Perspectives around Mathematical Teaching and Learning

We use perspectives to signify the views teachers and students hold about mathematics. Ambitious mathematics teaching entails perspectives around the learning of mathematics that diverge from traditional perspectives of instruction, in which the teacher dispenses information and models procedures that students then mimic (Singer-Gabella et al., 2016; Stigler & Hiebert, 1999).

The latter position mathematics as a rigid discipline with fixed concepts and procedures (Warshauer, 2015). AMT, by contrast, rests on assumptions that:

> mathematics is a dynamic discipline that involves exploring problems, seeking solutions, formulating ideas, making conjectures and reasoning carefully as opposed to a static discipline consisting only of a structured system of facts, procedures and concepts to be memorized or learned through repetition. (Warshauer, 2015, p. 377)

In AMT, mathematics is more fluid, dynamic, and locally generated. In addition, teachers expect students to struggle to solve complex tasks, in contrast with traditional practices in which students engage in predictable activity (Jacobs et al., 2006; Stigler & Hiebert, 1999). The complex tasks should be accessible and vary in complexity (Jackson et al., 2013; Stein et al., 2009). To promote student interaction, these tasks should be groupworthy, which means that they "promote and support collaborative learning interactions among students" and "more inclusive and equitable collaboration" (Crespo & Harper, 2020, p. 2).

Practice Demands: Interactional Norms

AMT involves increased complexity in student roles and what counts as competency, moving away from traditional forms of competency such as rapidly completing computational problems. Ambitious mathematics instruction changes what it means to be good at mathematics and how teachers recognize competency (Gresalfi et al., 2009). Students' roles in AMT entail greater authority and new forms of accountability, which means students must justify and explain their answers (Gresalfi et al., 2009). Teachers engaging in AMT provide students opportunities to exercise agency and share mathematical authority by contributing ideas, determining solution pathways, and making connections between school mathematics and out of school lives (Kinser-Traut & Turner, 2020). The new student roles also surface the complex identities of students in terms of race, ethnicity, and linguistic resources, further complicating the participatory demands of AMT (Zavala, 2014).

Demands Placed on Teachers, Instructional Leaders, and Administrators

The support necessary to address these demands on students requires that educators transform their knowledge, perspectives, and practices (Horn & Garner, 2022). The demands placed upon teachers induce demands on other personnel, including coaches, instructional leaders, and administrators.

Knowledge Demands: Mathematical Content Knowledge and Pedagogical Knowledge

AMT entails mathematical content knowledge and pedagogical knowledge demands on teachers and administrators (Coburn & Russell, 2008; Horn & Garner, 2022; Jackson et al., 2017; Lochmiller & Cunningham, 2019; Singer-Gabella et al., 2016). The use of challenging tasks requires that teachers have strong mathematical and pedagogical content knowledge (Ball et al., 2008; Charalambous, 2010; Wilhelm, 2014). Pedagogically, because AMT requires intellectual effort and risk on the part of students, it is likely to draw on and affect student identities in pronounced ways which requires teachers to engage in both interactive and reflexive positioning (positioning others and oneself in conversations, respectively; Wagner & Herbel-Eisenmann, 2009).

Perspective Demands: Perspectives around Mathematical Teaching and Learning

Shifting from traditional mathematics instruction to AMT entails new perspectives. Teachers and administrators must tolerate the frustration and uncertainty of watching students struggle with difficult problems (Warshauer, 2015). Similarly, allowing students to struggle entails a shift of mathematical authority away from teachers to students, which has implications for the distribution of power in classrooms (Gresalfi et al., 2009).

Practice Demands: Interactional Norms and Organizational Routines

AMT involves demands related to practices regularly carried out by administrators in their evaluations of teachers. For example, teachers need actionable feedback around such topics as language demands, learning from complex tasks, productive group work, and the orchestration of classroom discussion (Rigby et al., 2017). Furthermore, AMT entails demands related to leadership and decision-making, such as fostering distributed leadership (Larson et al., 2017). Other demands on organizational practices related to AMT include scheduling that provides for common planning time and workspaces (Sun et al., 2014).

External Demands

External demands emanate from outside the ambitious mathematics program and draw attention, time, and resources away from AMT. The multiplicity of demands involves different agendas and theories of action, complicating decisions for those in charge of interpreting and implementing the plethora of initiatives (Honig, 2006; Honig & Hatch, 2004). There can be deleterious impacts from navigating numerous initiatives. Honig (2006) states that "when multiple external demands converge on schools they compete with each other for funding, time, and attention in ways that have been linked with school mismanagement, poor instruction, teacher turnover, and other measures of weak school performance" (p. 16). Consequently, both the plethora of initiatives and the ways in which these demands compete with or contradict each other pose challenges.

Tensions Between Internal and External Demands

The extent to which internal and external demands compete for time, attention, and resources can be characterized by alignment, balance, and buffering, described below. When there is alignment and balance, we would say the system coheres in terms of its commitments to a particular reform. One way to maintain balance is for instructional leaders (e.g., the principal or superintendent) to buffer the impact of the external demands. Buffering refers to the ways that instructional leaders filter or temper external demands and thus how they impact teachers and students.

Alignment

Alignment refers to the extent to which external and internal demands entail similar knowledge, perspectives, and practices of stakeholders within the organization. There is the potential for internal and external demands to be in conflict, leading to tensions at various organizational levels that impact the ways in which educators identified and allocated resources in classrooms. A consequence of the potential conflicts between AMT (internal demands) and broader educational policies (external demands) is that stakeholders at different levels of school organizations may have different perceptions and commitments related to AMT. These differing perceptions may impact allocations of resources and how those most responsible for implementing AMT perceive organizational commitments to AMT. Without a sense of organizational commitment, teachers may decide the effort and risk necessary to transform their practice are not worthwhile.

Balance

Balance refers to two distinct phenomena. The first is the internal-external demand balance and the second is the demand-resource balance. These phenomena reflect the extent to which practitioners—those charged with implementing a reform—can commit their attention and efforts in ways that allow them to work through the challenges and stresses of implementing ambitious instructional practices. We explain each of these conceptions of balance below.

Internal-External Demand Balance

Stakeholders at all levels of an organization inevitably respond to many simultaneous policy initiatives. Honig (2006) notes if these initiatives are not manageable in scope or aligned, practitioners' attention and efforts are split between external and internal demands. If there is too much attention and effort paid to external demands, particularly when they are not aligned with internal demands, then a reform effort like AMT is unlikely to succeed.

Balancing multiple initiatives can reduce the attention to and effectiveness of any one goal (Fullan, 2011; Fullan & Quinn, 2015) and lead to initiative fatigue (Reeves, 2006). Each new initiative begins with a high level of energy but as systems add initiatives, sustained focus on any one enterprise is limited. The limited level of meaningfulness of initiatives and policies results in reduced efficacy (Nolan, 2018).

Demand-Resource Balance

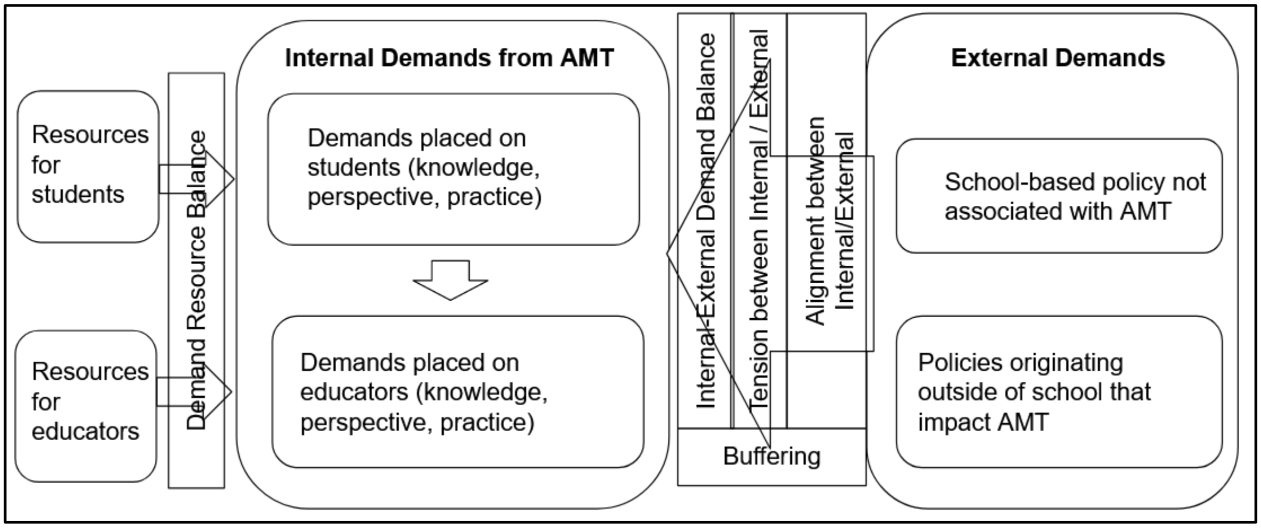
The notion of demand-resource balance reflects the basic proposition that resources must be made available to address demands as they emerge. Demand-resource balance begins at the inner core of classroom ecology - the student. If students do not feel supported as they encounter the demands of AMT they will be unlikely to persist in their efforts. Similarly, if teachers do not feel they have the requisite time, professional development, and collegial support to help students navigate these demands, they are likely to engage in the "default" or traditional educational practices. A complicating factor related to generating the capacity to meet demands is the time scale of developing resources. While there is an immediate need to support students to manage linguistic and other demands created by reform efforts, material resources do not translate immediately into the necessary human and social capital. Teacher capacity, and the capacity of those who support and supervise them, must be developed, which takes time. Consequently, alignment of resources with demands may entail a lag time between when educators identify demands and when they make appropriate resources available, and when educators develop the requisite capacity.

Buffering

Buffering refers to the ways that instructional leaders filter or buffer external demands and moderate their impact on teachers and students. Buffering allows those responsible for implementing reforms to focus on the internal demands imposed by the reform. School leaders act as mediators of district policy by influencing the implementation of the policy (Coburn & Russell, 2008; Crow & Weindling, 2010). School leaders who buffer external demands build trust with teachers (Leithwood et al., 2010), and allow teachers to focus on the reform initiative. DiPaola and colleagues (2005) stated that buffering protects teaching and learning by reducing distractions. See Figure 1 for a diagram of the framework.

Figure 1

Diagram of the Framework



Analytic Framework

We translated the conceptual framework into an analytic framework by first identifying three analytic tasks that used action verbs (e.g., identify, articulate) to guide the researchers and that encompassed the key concepts. We then translated the analytic tasks into analytic questions, seen in Table 1, that served as our research questions.

Table 1

Analytic Framework for Exploring the Demands, Tensions, and Resources Related to Sustainably Implementing an Ambitious Mathematics Program

Analytic Task	Analytic Questions
Articulate the demands placed upon students, teachers, and administrators	● What were the knowledge, perspective, and practice demands placed upon students as a result of implementing AMT? ● What were the knowledge, perspective, and practice demands placed upon teachers, instructional leaders, and administrators as a result of implementing AMT?
Identify the resources allocated to address the internal demands, the ways the resources addressed the demands, whether educators deemed those resources adequate (demand-resource balance)	● What resources did the EPO allocate to students and teachers related to AMT? ● How did those resources address the internal demands of AMT? ● Did the teachers, instructional leaders, and administrators deem the resources adequate to address AMT?

Analytic Task	Analytic Questions
Identify external demands that impacted the mathematics program, and articulate the ways these external demands aligned with or were in tension with AMT (alignment balance, buffering)	● What were the external demands that most affect AMT? ● In what ways did the external demands align with AMT? ● In what ways did the external demands conflict with or draw resources, time, and effort away from AMT? ● To what extent did the administrators and external consultants buffer teachers from external demands to minimize the tensions?

Methods

We used the implementation of AMT at the John Lewis School as an illustrative case (Kazemi et al., 2022) to explore the explanatory value of the conceptual framework. Though case studies have limitations with respect to generality, they can generate complex depictions of an educational setting and insights into broader phenomena (Stake, 2005; Yin, 2018). Stake (2005) suggests this methodology allows us to focus on people and programs in "integrated systems" (p. 2), using a flexible design to address research questions. The process of analyzing a case allows for a detailed development of the phenomenon by looking at the themes through an analysis of the data (Stake, 1995, 2005; Yin, 2018).

Data Collection

The lead author conducted 35 interviews from December 2020 to Spring 2022 with nine teachers, three teacher leaders (the teacher leader changed at the High School during data collection), four administrators, and six external consultants at John Lewis. We used multiple interview protocols to explore: various aspects of the development of the mathematics program; the instructional approaches emphasized in the mathematics program; the manner in which the program was implemented; the resources allocated to the implementation of the program; and the demands placed upon students, teachers, and instructional leaders related to the mathematics program.

Data Reduction Process

The project research team used a data reduction process using Saldaña's (2015) theming method to develop memos, collective memos, and supermemos. The lead researcher divided the transcripts into over 1000 passages whose lengths varied from 50 to 250 words, and then placed each passage into categories (e.g., implementation, instructional philosophy). To reduce the data, three researchers created one or more memo(s) for each passage. After reconciling these memos for each passage into a collective memo, a researcher grouped the collective memos for each category into supermemos, each of which had between 10 and 30 memos associated with it. The research team then collectively revised the supermemos to ensure the supermemos accurately captured key themes in the data. We intended the memos to be low-inference and parsimonious paraphrases of the original passages, while we intended the supermemos to represent themes emerging from the data. The research team created 78 super-memos in all.

Applying the Analytic Framework

For each analytic question, we searched for supermemos that corresponded to the question. For example, for the analytic question What are the knowledge, perspective, and practice demands placed upon students as a result of implementing AMT?, we identified the following supermemos as potentially relevant: lack of previous experiences with inquiry-based discussions and textbooks was challenging for students; the mathematics program required student collaboration, but many students did not know how to collaborate in the activities and share their ideas; and a high-level language in the reading-heavy curriculums was challenging for accessibility. We then re-read the original quotes associated with each supermemo, using the analytic question to interpret the data in a more focused way. Using this process, we identified key quotes that we then used to respond to the research questions. Our goal was to present an illustrative case study, so we focused on identifying data that corresponded to concepts in the framework. We wanted to gauge what insights the framework generated that extended our prior understanding of the implementation and sustainability of the mathematics program at John Lewis. In terms of external demands, we limited ourselves to the two most frequently mentioned initiatives, Understanding by Design ([UbD]; Wiggins & McTighe, 2005—an internal initiative) and high-stakes testing (an external initiative). Below, we present data related to the internal demands of AMT, the two external demands, and the issues of alignment, balance, and buffering.

Results

First, we describe results relating to the demands placed upon students, teachers, and administrators at John Lewis. Second, we describe results relating to the resources allocated to address the internal demands, the ways the resources addressed the demands, and whether educators deemed those resources adequate. Third, we describe results relating to the ways external demands aligned with or were in tension with AMT.

Internal Demands Related to the Mathematics Program

In this section, we respond to the analytic questions of what knowledge, perspective, and practice demands that the implementation of AMT placed upon students, and what knowledge, perspective, and practice demands the implementation of AMT placed upon teachers, instructional leaders, and administrators.

Demands on Students

Knowledge Demands. One of the primary knowledge demands cited by teachers was the language demands placed on students. Teachers at both the Middle and High Schools described the challenges of the high reading levels of the curriculum materials. Lattimore, a teacher at the Middle School, stated, "[CMP] is a very text-heavy program … I think we struggle because there's a very high level of reading within the materials." Owens, a High School teacher leader, explained "I think that the biggest challenges have been around reading comprehension and vocabulary," around which multiple issues arose, including "the reading level of some of the problems, or sometimes situations that are unfamiliar, that they have trouble relating to a context." Carter, a High School teacher, similarly stated "the text was too dense and they weren't engaging with it." Not all the teachers viewed the language demands in purely negative terms. Rafferty, a High School teacher, stated:

> It is good practice to expose the students to high level reading and language, … but I also see how it's a barrier to them and it can cause some students to shut down and just never get to that math concept.

Teachers also mentioned the cognitive demands related to the ambiguity of potential solution methods. Matthews stated "There's a lot more gray ... there's lots of times more than one right way to solve a problem as opposed to the rote approach where it's typically 'Here's the method that works.'"

Perspective Demands. The teachers described how students struggled to work on problems for which they had not been given an established procedure. Carter explained the challenges of getting students to work on problems that were non-routine, stating it "is a big challenge because when you get an open-ended question that seems so daunting than just a closed, 'What's the first step, divide by three.'" Matthews stated that it was a challenge for students to adjust to the expectation that they would identify their own approaches rather than follow one provided by the teacher:

> When it gives you that opportunity to think about problems … and not in a direct way … a lot of our kids are used to having one solution path or being funneled …. That lack of direction initially can really cause them to struggle in just getting started ... They're not used to having to take things they've learned and apply them to a new context.

Davis explained a similar phenomenon with his Middle School students:

> When you have students that are used to, "Tell me what to do," because they've learned over years that they're going to be told how to do … there is a sense of comfort in that. … we have some students that will feel uneasy when it is this open-ended problem like, "Wait, what? I get to call the shots? I get to try things out?" but without the confidence of knowing where to start.

Practice Demands. The teachers noted expectations for increased collaboration, and that students were not accustomed to working with other students or listening to their explanations. Matthews explained:

> There's certainly a much more collaborative social component to the curriculum. It's designed to be using group work and discussion and using the ideas of other students in the class to think through and develop your own ideas into—as a class, construct those math understandings based on our various experiences in ways of thinking through problems.

Riggs, a High School teacher, explained:

> It's hard for them to express their ideas. I would say the confidence that comes with—there's sometimes a hierarchy in math in a classroom where the low-level students are very afraid to speak because they don't want it to be wrong in this way. Those challenges arise and prevent students from talking about their ideas and also prevents them from discussing their ideas in class.

Similarly, Rafferty explained "a lot of times they'll just sit there in silence, sitting in a group not talking to each other … it's not necessarily natural for them to talk to each other about math."

In summary, teachers identified knowledge, perspective, and practice demands on their students associated with the implementation of the mathematics program. They noted how these demands differed from traditional programs that emphasized rote procedures and that largely constituted students' prior mathematical experiences.

Demands on Mathematics Educators

In this section, we focus primarily on the demands placed upon teachers. We implicitly describe the demands placed on teacher leaders and administrators in the subsequent section on the demand-resource balance, in which we describe various forms of support provided to teachers.

Knowledge Demands. The teachers talked about the need for a deeper understanding of mathematical content to use the curriculum materials to respond to and build on student thinking. Matthews stated, "You need to know a lot more and be a lot more flexible with your knowledge." Rafferty stated that a challenging aspect of using the materials was:

> making sure that I know the content deeply before I try to teach it, making sure that I really understand what understandings are meant to come out of an investigation. For example, not that I just know how to use the quadratic formula or something, but that I really understand the concepts.

Perspective Demands. The teachers described how the mathematics program was different from how they had learned mathematics and was more difficult to teach than a traditional program. Franklin explained:

> It's a very different way of teaching than what I experienced as a student [in Germany] …. I've been playing with the curriculum in different capacities for about 10 years now, but it's a really difficult way to teach. Direct teaching is much easier to facilitate, and it's easier to see student success in the short term.

Matthews similarly explained that "a big challenge is that you have to make sense of [the materials] first, that this is not how most of us learned math. We mostly learned math in that transmission model."

Practice Demands. Implementing the mathematics program entailed practices that were more difficult and time-consuming than using traditional materials. Franklin explained how lesson planning was more difficult, "Teaching in this inquiry type way, it's harder to plan because you don't know what kids are going to say. You have to imagine all the different things that might happen…it takes a lot more planning." Matthews similarly explained that that planning required:

> taking the time to do … all the thinking through a lesson that was required that you wouldn't need if you were just going to show kids how to answer a type of question and then have them practice it.

He added that having to "navigate the different things that kids might come up with takes a lot of extra planning."

Rafferty explained the challenges of letting her students struggle:

> [teaching from Core Plus] is definitely a lot harder. You want to make sure that you're intentional about what problems you are spending time on. How much time you give them to struggle before you jump in? … I don't want to stop at a table and they're stuck and I don't want to just like ask them a bunch of leading questions so that they can get the right answer. I really need to think about how I can ask them questions to push their thinking, but not necessarily lead them to a particular answer.

Two teachers explained other aspects of their practice that required more attention. Rafferty explained that "It's hard, especially with the language demands of Core Plus … Sometimes I try to find extra resources for those students, whether it's something online that they can watch that's in their language or whatever." Franklin described how she needed to spend time establishing norms at the beginning of the school year, "It also takes a different way to set up working collaboratively in this classroom."

Demand Resource Balance

In this section, we respond to the analytic questions of what resources the EPO allocated to students and teachers related to AMT, the ways in which those resources addressed the internal demands of AMT, and whether teachers, instructional leaders, and administrators deemed the resources adequate to address AMT.

Resources Provided to Students

In response to the demands on students, the teachers modified the materials to help students navigate the materials while maintaining the mathematical focus. Lattimore stated, "We make the accommodations … especially in the beginning of most of the investigations and sometimes in each of the units ... [the students] sometimes have to highlight key words or phrases." Owens stated that "we've ended up adjusting, … we take a paragraph, and can summarize it into a few more concise sentences that get the point across." Matthews, a High School teacher, stated "We've tried to eliminate some of that challenge by rewording things or using a different context that might be more relevant to them but keeping the foundational concepts there math-wise." Shepard, a High School teacher, explained how she supported students to engage in discussions:

> One of our norms is I can listen to others' voices and ideas, and I can build from others' ideas as well. Whenever they do that, I post it. When they're doing it, I validate the ones that are doing it really well, which helps because they all want their names on the board. It's a big deal for them.

Some teachers expressed that there was inadequate support for struggling students and students who were English language learners or who were labeled as having disabilities. Franklin, a teacher leader, noted that the Support Room (a dedicated space where students could go if they needed extra assistance in mathematics) was not always staffed by a certified mathematics teacher. The teachers also explained that because mathematics classes met every day while other subjects met every other day, the co-teacher for ENL students or students with IEPs was only present for half of the classes. Shepard mentioned that her classes were not always balanced, and that she often had classes composed almost entirely of students who had disabilities, which made it difficult for her to support her students without additional staff.

Resources Provided to Teachers

All nine teachers we interviewed stated that there was adequate support provided to them in terms of understanding the materials and developing instructional practices. In the first years, the EPO gave the teachers two weeks in the summer to plan curriculum and more time during the year. A few of the Middle School teachers went to workshops in Michigan for additional training on the CMP program.

The teachers explained that the support they received was focused on understanding the curriculum materials and associated instructional practices, which they found helpful. Rafferty, a High School teacher, explained some of the curriculum-specific support, "We've had consultants give us professional development on the Launch, Explore, Summarize structure of a Core Plus lesson, giving us examples, having us work through a student lens." Owens similarly explained that the consultants from the EPO helped the teachers understand the content in the materials by working through the investigations:

> Working through the problems with one another, and discussing what math should be coming out of the investigations so that we know where we're trying to

> develop—where we're trying to focus the conversation when we're teaching it, has been really helpful.

Franklin described the intensive curriculum-specific training they received in the initial years:

> The first summer, we all did unit training with the CMP3 curriculum … Each teacher participated in training based on the grade level and we really did a deep dive. It was at least one solid week of every day just going through the math that you would experience and talking about it from both as a student and then talking about teacher moves as well.

Rafferty also explained the support the teachers needed with regard to the interaction protocols:

> We've had lots of training on the Managing the Active Classroom protocols. That first year I was like, "Oh, well, these aren't going to apply to math." Then you have to just get creative in thinking about how you can use them.

The EPO devoted considerable resources and expertise in the initial years to help teachers develop familiarity with the curriculum programs and the instructional practices aligned with the programs. Though the teachers stated that the program was challenging to implement, they stated that there had been adequate resources devoted to the implementation of the program.

External Demands

In this section, we respond to the analytic questions of what external demands most affected AMT, the ways in which these external demands affected AMT, the ways in which the external demands were in tension with AMT, and the ways that administrators tried to minimize the tension. We focus on two external demands—a school-based initiative (the implementation of processes associated with Understanding by Design ([UbD, Wiggins & McTighe, 2005) and high-stakes assessments—that most impacted the implementation of the mathematics program.

Alignment with the UbD Initiative

UbD was pushed by the EPO's chief academic officer to connect the curriculum in all subjects to essential content, which in part was defined by the content on state-level assessments. The UbD process involves articulating essential learning goals and then stipulating intermediate objectives and activities designed to meet those goals. In this process, educators identify key understandings and essential questions, which they use to guide development of assessments to determine whether they meet learning goals. Lester, the external consultant guiding the UbD process, stated that UbD "is a lens to talk about the big ideas in a unit of study and how the specific content skills help the students to come away with those generalizations that are represented by the big ideas." She further explained that the process starts with the "end goals and then in turn the inquiries we would want to use to ensure that kids were prepared for that assessment." Lester saw UbD as a way to align content with the state assessments, stating "I think the focus of the UbD process became … the prioritized content and skills aligned to those [state] tests… The assessments … were focused on those contents and skills that were heavily tested on the Regents test."

Mathematics was the only subject area for which the school adopted established curriculum textbook programs. Furthermore, the textbooks provided key understandings, essential questions, and assessment items. Consequently, for the mathematics program at John Lewis, UbD was largely a parallel process that, while potentially aligned with the philosophical intent of the materials, required additional time beyond what teachers were already doing to teach from the adopted curriculum materials. Lester explained that the mathematics department initially "defined the lessons that were part of the inquiry program that would best meet the outcomes," but then a new principal came in and said, "Well, if we're using UbD, shouldn't the units [in all of the content areas] be written in a UbD format?" This led to an effort to rewrite units of study using the UbD format.

Some participants viewed UbD as a competing initiative. Alder, a teacher leader, explained that initially "our focus was in how we develop mathematical ideas," and that UbD "was one of the pieces that we started adding." Deprez, the external consultant who supported the mathematics department, explained that an outcome of the UbD process was to produce units that could be disseminated beyond the EPO, which was seen as justification for the extra resources devoted to the EPO relative to other schools in Fullerton. She stated:

> They've been told they have to write this curriculum to share across [the district], and so they fill in the boxes. …. the rush to create [units] makes people feel like they don't have time to really be thoughtful and to internalize all of that.

Others saw UbD as potentially aligned with the intent of the mathematics program. Matthews explained how the UbD process helped teachers evaluate which student approaches were productive. He explained that "backwards design" helps to identify "which questions you want to ask," concluding that "If you're not clear about where you want kids to wind up, you're going to really struggle to figure out which of those responses are valuable." Deprez described how she tried to align UbD with the external consultants' vision of the math program. She explained how the *transfer goals* from Stage One of UbD was related to "this idea that we're working towards [students] having the ability to provide specific mathematical evidence, explain their thinking and writing at the appropriate level." She added that this helped teachers focus attention on the learning goals manifest in the transfer goals.

In summary, UbD was largely viewed as a parallel, competing effort to articulate the mathematics curriculum. In principle, there was alignment between the purposes of UbD and identifying appropriate goals and activities in the adopted curriculum materials, as noted by some participants, but the delayed timing of the implementation of UbD was seen as creating additional work that distracted from efforts to implement the curriculum materials.

Alignment with Focus on State Assessments

Participants expressed that the state assessments did not align with the principles of an inquiry-based program, even though success on the assessments was seen as a necessity. Marshall, a consultant, explained how the consequences of high-stakes tests made focusing on them a priority, even though doing so contravened the beliefs of the program:

> The administrator [stated] we have to pass these tests. Everything we do has to be in service to passing these tests. …That's not what we believe at all, but the reality of this situation is if we didn't do well on those tests, the school would close.

Lester described the tension between these competing initiatives, explaining that there was "a tension between those who were … trying to keep the program an inquiry-based program [and] those who were interested in giving kids more practice and more exposure to what was on the [state test]." Shepard, a High School teacher, described how the emphasis on the Regents was detrimental, saying "the coaching [at one point] was very test-driven … which I feel like it just takes away from the program."

The focus on the state assessments had a pre-EPO history that created tensions when the EPO adopted inquiry-based mathematics programs. Farrell, the High School principal, stated:

> there were tensions that arose. I think many people were used to just preparing for the [state test], or just pouring information and giving kids the information instead of

> activities that would allow the kids to reflect and engage and come to their own conclusions.

Johnson, the chief academic officer of the EPO, similarly explained her difficulties convincing High School teachers to buy into the inquiry-based program, "It was a hard sell … to keep the math teachers focused on conceptual understanding when they really had a very clear picture in their mind of specific skills."

The emphasis on the state tests had a direct impact on classroom practices. Rafferty explained how the exams pushed teachers to give students extra practice on a skill:

> In Algebra Two we still have these [state tests] … looming over us. … teaching the quadratic formula … sometimes I do just need to practice it multiple times to be able to understand it … [so] here's five problems to do with the quadratic formula.

Not everyone saw the inquiry-based program as out of alignment with success on the state test. Friske, an external consultant, explained how the inquiry-based program would help students do well on the test, saying that passing the exam was "a minimum expectation" for the rigor of the program, adding "passing a [state test] is just a hiccup along the way."

In summary, the participants saw the state assessments as competing philosophically with the focus on inquiry and conceptual understanding. The consultants and teachers explained how the focus on test content entailed a procedural focus at odds with the inquiry-based focus of the curriculum materials.

Balance

Internal-external demand balance refers to the extent to which other initiatives fragmented teachers' focus on the mathematics program. We already described the impact of one school-based initiative, UbD, on the implementation of the mathematics program, but there were other initiatives as well. Ransom, the Middle School principal, described the plethora of initiatives:

> So we've provided training on UbD, which is the way we write curriculum. We've provided training on Managing the Active Classroom. It's kind of crazy, the amount of things we've done. Deliberate Practice, which is the way we teach the lessons. We did a whole year on learning targets, and then we did a whole year on feedback. Let's see, and this year specifically we've done professional learning on digital instruction [and] professional learning specific to the math program … . Oh, and trauma-informed instruction.

Marshal, an external consultant, explained how focusing on so many things at once detracted from a focus on student learning:

> While we had learning principles and while we had curriculum materials that were supportive of those learning principles, we felt that the focus from administration was on the teaching and not on the learning. … There was a missed opportunity at the launch of John Lewis School to spend the first year not talking about teaching, not talking about UbD, not talking about Expeditionary Learning.

Lester similarly described the impact of attending to multiple initiatives, stating "there's been a lot of initiatives school-wide … It's trying to find how this math program connects to some of those school initiatives." These perspectives indicate that attending to multiple distinct initiatives simultaneously was costly and stretched teachers' attention and diminished opportunities to focus on student learning rather than teaching and planning protocols.

Buffering

In terms of the high-stakes assessments, the administrators described their commitment to the mathematics program despite the pressures to perform well on the state-level assessments. Farrell, the High School principal, stated "We found our balance of how we could implement things with fidelity and supplement things that were needed but did not allow the supplementation to take over the purpose of our inquiry-based program." Davis described how Ransom, the Middle School principal, was, "very supportive, to the point where—I think it was two years ago—we were heavily encouraged by her to be using the curriculum with more fidelity than we had been."

In terms of the UbD initiative, a number of participants described how the external consultants shielded them from rewriting units. The teacher leaders and consultants created a buffer by writing the initial UbD units and providing high levels of support for the UbD units written by the teachers. This buffering allowed teachers to focus on implementing the mathematics program. Deprez, the external consultant who supported the High School mathematics teachers, explained that she and another external consultant "spent a summer writing Stage One documents for every unit for all three of the Regents' level courses." She explained that they did so because the administration felt that "teachers hadn't really internalized and made sense of the curriculum in a deep enough way to be able to identify big understandings and essential questions." Alder, a High School teacher leader, explained that she needed support from the consultants because of the ongoing work implementing the curriculum materials, "we definitely needed … external support from the consultants … because we were writing the curriculum at that time, writing UbD units, but we're also implementing the curriculum at the same time." She explained that the support from the external consultants decreased as each subject area team gained more expertise, "They provided that support with writing UbD with Algebra 1. ... Once the team reached mastery [so] they could write [UbD units] alone, they pulled out."

In summary, buffering occurred in two ways. First, despite the concern and emphasis on the state assessments, the administration remained committed to the mathematics program and continued to express support and devote resources to implementing the curriculum materials. Second, the workload of the UbD process, especially at the High School, was borne by the external consultants, in part because administrators recognized them as being more knowledgeable of the curriculum and because the teachers were already devoting considerable effort to understanding and implementing the curriculum materials.

One limitation of this study should be noted. Due to the timing of the funding, data collection began in Fall 2020, during which instruction was conducted online. Consequently, our data are largely retrospective accounts of the program as it existed pre-COVID. We have conducted interviews and observed classes after in person teaching resumed in the Fall of 2021, but it is as yet difficult to estimate the impact on the implementation of AMT of 18 months of online instruction.

Discussion

We set out to understand the demands and tensions involved when a school in a high-need setting implemented an ambitious mathematics program. We created a framework that explained the demands and tensions related to AMT in terms of alignment, balance, and buffering, which all speak to the resources and coherence necessary to sustain such an implementation. The framework focuses on the tensions between internal and external demands and how alignment, balance and buffering mitigate or exacerbate these tensions with respect to the ways organizations engage in multiple initiatives and allocate resources. We described the extensive and multifaceted nature of internal demands related to AMT and how these demands created tensions with respect to whether the EPO made adequate resources available to address the demands and the extent to which these demands aligned with or in tension with other initiatives in which the school engaged. The framework helped us generate a coherent perspective of the implementation of the program and, more importantly, identify persistent challenges to implementing AMT in a high-need context. Furthermore, the framework helped us to articulate distinctions between internal and external demands and to understand how the two sets of demands interacted with each other.

Internal Demands and Demand-Resource Balance

Educators at the EPO struggled with the internal demands we outlined in the framework. The teachers specifically noted that the curriculum materials placed language demands upon students, students struggled to adjust to expectations that they would generate their own approaches when solving problems, and students had difficulties collaborating on problem solving and participating in class discussions. In terms of the demands on teachers, there was an increased expectation of content knowledge, especially with regard to conceptual understanding of mathematics, what it means to learn and teach mathematics, and increased time and effort with respect to planning with the materials.

Given the numerous demands placed on teachers and students, we explored whether educators perceived that there were adequate supports. The teachers reported providing a range of support to students to address the demands, particularly the linguistic and participatory demands. Despite these supports, COVID and ongoing challenges for teachers exacerbated these demands (Choppin & Merliss, 2022). These challenges pose a threat in terms of teacher fatigue and loss of focus on ambitious forms of instruction. In terms of demands on educators, the teachers expressed that the EPO generally supported the mathematics program and devoted the necessary resources to address those demands. The exceptions related to students who needed more intensive assistance, especially students with disabilities and students who were English language learners. Teachers expressed that there could be more dedicated support for these students.

Tensions Between Internal and External Demands

We explored the impact of the tensions between internal and external demands with respect to a school-based initiative and to a state- mandated initiative, the UbD process and high-stakes assessments, respectively. In terms of alignment, we found that, though the UbD process potentially aligned philosophically with the mathematics program in terms of identifying and focusing on essential ideas, the timing of the UbD process drew time and attention away from ongoing efforts to understand how the curriculum materials fostered opportunities for student learning. The external consultants and teachers saw the high-stakes assessments as conflicting philosophically with the inquiry-based nature of the curriculum materials, in part because they led to instructional practices that focused narrowly on procedures emphasized in the assessments.

With respect to the internal-external demand balance, the plethora of initiatives stretched teachers' attention and diminished opportunities to focus on student learning. Several administrators and consultants explained that the quantity of these initiatives was overwhelming and detracted from a focus on implementing the mathematics program. With respect to buffering, we found that buffering occurred in two ways. First, despite the concern and emphasis on the state assessments, the administration remained committed to the mathematics program and continued to express support and devote resources to implementing the curriculum materials. This helped the teachers persevere when encountering challenges. Second, the workload of the UbD process, especially at the

High School, was initially borne by the external consultants, which provided time for the teachers to develop a better understanding of the curriculum materials before doing the UbD process.

Policy Implications

The results provide insight for policy makers with respect to the resources and coherence necessary to support educators and learners who are involved in ambitious reforms. The EPO was unique in terms of its intensive commitment to curriculum development, sustaining the use of inquiry-based curriculum materials in a high poverty school, providing considerable resources to teachers to enact ambitious instructional practices, and providing extra support for students. The result was a reasonably strong implementation of the mathematics program. However, there were tensions that diminished some of the potential benefits. First, the EPO tasked educators with familiarizing themselves with instructional materials that represented a stark departure from the previous materials. Simultaneously, the EPO asked teachers to embark on an intensive, long-term curriculum writing process that required additional time and effort which detracted from the initial efforts to focus on student thinking. Second, high-stakes testing constrained the flexibility of the teachers to provide the time for students' productive struggle and sensemaking. While policy makers are accountable to constituencies that demand evidence of success and of the labor of teachers, they need to attend to the ways in which policies articulate conflicting perspectives and stretch finite resources.

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About the Authors

Jeffrey Choppin
University of Rochester
jchoppin@warner.rochester.edu
https://orcid.org/0000-0002-2256-4320
Jeffrey Choppin is a Professor of Mathematics Education whose research interests have focused on the nature of classroom discourse, the interaction between teachers and curriculum materials, the impact of educational policy on classroom practice, and the professional development of mathematics teachers. Before becoming a mathematics teacher educator and education researcher, he was a classroom teacher of mathematics for 12 years in the Washington DC Public Schools.

Christine Green
State University of New York at Geneseo
greench@geneseo.edu
https://orcid.org/0000-0002-0841-6057
Christine N. Green completed her Ph.D. in Teaching and Curriculum and her M.S. in Educational Leadership at the University of Rochester. She is an Assistant Professor of Education in the Reading and Literacy Department at the State University of New York at Geneseo. Her research interests center on curriculum development and multiliteracies with a focus on the impact of progressing technologies on the social and cultural context of learning.

William Zahner
San Diego State University
bzahner@sdsu.edu
https://orcid.org/0000-0002-2823-0436
William Zahner is an Associate Professor in the Mathematics and Statistics Department at San Diego State University. Zahner's research focuses on creating classroom learning environments in which multilingual students in secondary mathematics classrooms can thrive and learn robust mathematics.

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