# CURRICULUM METAPHORS IN U.S. MIDDLE SCHOOL MATHEMATICS

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*We describe two metaphors that we hope can be used to better understand the contemporary mathematics curriculum context in U.S. middle schools, to see how this new context is both similar to and different from prior curriculum contexts. We explain the role and positioning of middle school mathematics curriculum materials over the last century or more and build from learning theory to develop the metaphors. The first metaphor, curriculum as delivery mechanism, builds from technical rational or scientific discourses and encompasses perspectives that are so pervasive they are often unstated and unquestioned. The second metaphor, curriculum as epistemic device, posits that role of curriculum is to provoke interactions that generate understanding. In this metaphor, the role of tasks in curriculum materials is to provoke and progressively refine student thinking, individually and collectively.*

Keywords: Curriculum Design; Middle School Mathematics; Learning Theory

## Purpose

The U.S. curriculum context is rapidly changing with the increased use of digital and open source materials, the introduction of the Common Core State Standards, and the expansion in the numbers of individuals and organizations involved in curriculum development. In an effort to better understand how this new context is both similar to and different from prior curriculum contexts, we explore two curriculum metaphors that encompass broad trends in the role and positioning of middle school mathematics curriculum materials over the last century or more. The first metaphor, *curriculum as delivery mechanism*, encompasses perspectives that are so pervasive they are often unstated and unquestioned. This dominant metaphor appeals to modernist discourses of science and technical rationalism that permeate educational and other policy contexts (Datnow & Park, 2009) in spite of decades of work to deconstruct such discourses (cf. de Alba et al., 2000). Language referencing the dominant modernist or scientific perspective is often used to market products ostensibly developed using rigorous scientific methods. We deconstruct this metaphor and its manifestations in curriculum materials to highlight its influence on learning opportunities in middle school classrooms. Our goal is to highlight the nature of teachers' work and decisions when working with these materials and the impact of those decisions on the educational experiences of middle school mathematics students. We then describe an alternative metaphor, *curriculum as epistemic device*, which is implicitly if not explicitly evident in some curriculum programs, including those developed as a result of National Science Foundation (NSF) funding in the 1990s and 2000s.

## Perspective: Curriculum as Tool

In order to explore how curriculum design gets taken up by various stakeholders, we employ a perspective that considers human cognition in terms of action that is mediated by resources and tools situated in particular contexts (Engestrom, 1999; Pea, 1993; Wertsch, 1998). That is, human knowledge and understanding are manifest in action, which is mediated by the available tools and resources in ways that align with a person's goals and purposes. This contrasts with the idea of cognition as something that strictly happens inside the head of individuals and which has universal attributes. The context in which human action / cognition takes place influences the nature and goals of activity, division of labor, mediating artifacts, and discourse channels (Engestrom; Gee, 1999). With respect to curriculum, resources are deployed or mobilized in relation to the characteristics of the teacher and the curriculum program, prior teacher-curriculum interactions, and the curriculum goals of the teacher (Brown, 2009). Given the situated view of cognition from which we operate, we see teachers as curriculum designers, in that they exercise agency as they draw from resources in curriculum programs to design lessons, inevitably altering the resources in ways big and small (Ben-Peretz, 1990; Remillard, 2005).

The nature of curriculum materials influences the actions of the teacher and transforms both the goals and the activities of the teacher, while simultaneously the teacher employs the resources within curriculum programs according to a given history (personal, organizational, and political) and context that mediate how the resources are taken up (Remillard, 2005). Curriculum resources include representations of mathematics, representations of mathematical tasks and instructional activities, articulation of instructional goals, recommendations for lesson structure and requisite materials, and so forth. Because the enacted curriculum is a dynamic and interactive process of co-constructed activity between teachers and students (Ball & Cohen, 1996), curriculum resources are transformed as they are enacted in classrooms, with the enacted curriculum varying in ways both anticipated and unanticipated by the designers or teacher. The intended written curriculum is thus an inert form of curriculum that becomes 'lived' when enacted in classrooms (Guedet, Pepin, & Trouche, 2012).

## Methods/Modes of Inquiry

This paper is primary conceptual and theoretical in nature; nevertheless, we describe the process by which we came to consider these metaphors. First, we turned to prior research which suggests that, in most U.S. middle school classrooms, the typical lesson consists of teachers explaining a topic, modeling a particular procedure or skill, and then having the students independently work on sets of problems around that problem or skill, with minimal solving of complex or novel problems (Jacobs, et al., 2006; Stigler & Hiebert, 1999). This pattern reflects the presentation of mathematics in most middle school curriculum materials, which follow a similar explain-model-independent practice-problem solving (predictably applying the skill just practiced) sequence. This pattern also reflects the delivery metaphor.

The curriculum as epistemic device metaphor emerged from a five-year study of teachers using the Connected Mathematics Program (CMP) curriculum program (Lappan et al., 1998, 2006), conducted by the lead author. In this study, two of the teachers used the materials in ways quite distinct from their counterparts (Author, 2009, 2011a, 2011b, 2011c). These two teachers attended closely to student thinking, typically using the initial tasks in an instructional sequence to elicit students' informal reasoning. Subsequent tasks were used to refine and develop students' reasoning and the language used to describe mathematical concepts and relationships. In short, these teachers used the tasks in the curriculum materials as a means of eliciting and refining students' reasoning, language, and strategies.

A current project involving all four authors and a national sample of middle school teachers using materials from six different curriculum programs has provided corroborating evidence that these metaphors can be used to describe the practices of many of these teachers. However, the metaphors needed a stronger conceptual treatment in order to be useful for developing analytic categories to describe teachers' understanding and use of curriculum materials. In order to develop the metaphors, we have been reviewing literature on the history of mathematics curriculum trends in the U.S., on teachers' understanding and use of curriculum materials, and on theories of learning. Our ongoing synthesis of these literatures is presented below.

## Dialogic and Monologic Functions of Text

The two curriculum metaphors are distinguished largely by the extent to which their primary goal is to transmit information or to promote dialogue. Wertsch and Toma (1995), citing Lotman's work, discuss the dual functions of text as monologic and dialogic. The monologic function follows the delivery or conduit metaphor (Reddy, 1979, as cited in Wertsch and Toma), in which the main functions of text are encoding, transmission, and decoding. The monologic function is the primary function of curriculum as delivery mechanism, with an implication that messages as encoded in text or curriculum can be delivered with fidelity. Lotman describes the dialogic function of text in terms of text as *thinking device* in which the "main structural attribute of a [dialogic] text is its internal heterogeneity" (Lotman, p. 37, as cited in Wertsch and Toma) and second is that of a *generator of meaning*. Internal heterogeneity refers to the extent to which different approaches or interpretations are afforded. These different approaches or interpretations are generators of meaning when their differences and underlying similarities are made explicit, in the process generating new understanding or meaning in that community. We thus consider that the dialogic function of curriculum materials is to promote *interactions that generate understanding* and consequently emphasize the term interactions rather than dialogue in our discussion below. Although all texts simultaneously have monologic and dialogic functions, Wertsch and Toma (1995) state that "communication models based on the unidirectional transmission of messages cannot be amended in any simple way to deal with the issue of texts as thinking devices" (p. 166), suggesting that there need to be a priori decisions made about which function to emphasize. Thus, curriculum can be thought of as text that primarily serves as a generator of interactions or as a conduit to transmit information or knowledge, with the design situated near one pole or the other.

## Two Contrasting Curriculum Metaphors

Below, we unpack each metaphor in terms of its broad historical and epistemological foundations. We then describe how each metaphor is manifest in existing U.S. middle school curriculum programs. We then describe each metaphor in terms of task design, how teachers are positioned, and the underlying principles of curriculum development. First, we discuss the nature of tasks and how they provide opportunities to initiate dialogue and then we describe how teachers are positioned in this metaphor. We conclude with implications regarding learning experiences engendered by materials from each metaphor, the curriculum features essential to each metaphor, and the kinds of teacher understanding entailed by each metaphor.

### Curriculum as Delivery Mechanism Metaphor

The first metaphor, *curriculum as delivery mechanism*, speaks to the perspective that the primary goal of curriculum is to transmit information and knowledge. In the U.S., this perspective has a rich and long tradition. Curriculum as delivery mechanism stems from the technical rational approach to curriculum that has been the predominant curriculum perspective over the last century in the U.S. and was first espoused in the early 1900s (Kliebard, 1975). Early adherents to the technical rational (also termed scientific) approach, such as Bobbitt (1918, 1924) and Charters (1923) describe curriculum development as entailing a highly detailed analysis of disciplinary experts' knowledge and performance, rather than activity from the perspective of the child. Rigorous analysis of expert knowledge and task analysis of expert performance ostensibly are performed to identify the discrete bits of knowledge and skills that, when mastered, constitute competence in a discipline (e.g., the mastery perspective). Of this approach Gravemeijer (2004) states:

> Older design principles take as their point of departure the sophisticated knowledge and strategies of experts to construe learning hierarchies… The result is a series of learning objectives that can make sense from the perspective of the expert, but not necessarily from the perspective of the learner. (p. 106)

Bartell, T. G., Bieda, K. N., Putnam, R. T., Bradfield, K., & Dominguez, H. (Eds.). (2015). *Proceedings of the 37th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. East Lansing, MI: Michigan State University.

The discrete bits of knowledge have the added property of being more easily measured than broader, more complex, and consequently ill-defined knowledge (Eisner, 1967). This property extends the appeal of the technical rational approach to those interested in developing psychometric methods to assess student learning and thus to policy makers who wish to use assessments of student achievement data to gauge teacher and school effectiveness (Datnow & Park, 2009).

This approach appeals to modernist notions of scientific advancement by ostensibly employing disciplinary rigor. Although actual attempts to develop curriculum using this approach have been critiqued as impractical and ultimately subjective (Eisner, 1967; Kliebard, 1975), claims of scientifically-based approaches persisted through the 1900s and are currently evident in the marketing of publisher-developed curriculum programs (defined as those programs developed by large publishers, according to perceived market demand) and neo-liberal educational policies related to assessment and accountability. For example, see the debates around the use of terms such as 'scientifically-based research,' 'evidence-based,' 'high-quality,' or 'rigorous' (Darling-Hammond & Youngs, 2002; No Child Left Behind, 2002; Schoenfeld, 2006; U.S. Department of Education, 2002, 2003). Mainly, the modernist or scientific discourse is used to market an approach or product, while the scientific or rigorous nature of the process is rarely explained or examined in detail.

Curriculum development in the technical rational approach embodies the delivery metaphor, in which knowledge can be detached from an authority or expert (i.e., textbook, teacher) and transmitted to the novice learner (student), what Jackson (1986) calls the mimetic tradition. In the technical rational approach, expertise flows directly from the expert or authority to the learner, allowing those far from classrooms to exert control over content (Datnow & Park, 2009), thus minimizing the role of the teacher. Schoenfeld (2006) describes what he terms traditional U.S. curriculum materials in the following way:

> For most of the 20th century, the dominant perspective on learning in most fields, and specifically in mathematics, was that learning is the accumulation of knowledge; that practice solidifies mastery; and that knowledge is demonstrated by the ability to solve particular (well-studied) classes of problems. (p. 15)

The mastery perspective in this metaphor focuses at the scale of lesson or topic, with mastery expected on one topic before proceeding to the next. Furthermore, the transmission approach inherently entails a deficit view of the learner. The curriculum design is based on explaining and modeling concepts and procedures, which presumes that the learner has minimal understanding of the subject matter or intuitive understandings on which to base instruction. The treatment of language in curriculum materials from the delivery metaphor mirrors the treatment of mathematics content. There is typically an emphasis on early formalization and precision, with little validation of less formal or everyday terminology. In general, terms are defined and explained before students have had opportunities to explore the content.

The delivery approach is so pervasive that there is typically a minimal effort to explain the learning model beyond appeal to a mastery perspective. That is, there is little overt description of an instructional philosophy or theory of learning in the curriculum materials, especially publisher-developed programs. Furthermore, authorship of the materials is often anonymous, with only a listing of the experts consulted during the development process. Distinctions between curriculum programs developed through this approach usually entail the scope and sequence of content, the aesthetics of the materials, and the ancillary materials that are emphasized by publishers to market the materials.

Dissatisfaction with materials developed from this perspective has been longstanding, widespread, and multifaceted, with critiques focusing on the passive nature of student activity (National Council of Teachers of Mathematics, 1989), the coherence and rigor of the materials (Schmidt, McKnight, & Raizen, 1997), unexamined issues of power and identity (c.f. Gutierrez, 2002), and the limited role of the teachers as presenters of content (Confrey, et al., 2008). This dissatisfaction has led to numerous attempts to transform mathematics curriculum, including systematic and well-funded efforts, such as those associated with the New Math era and the programs funded by the National Science Foundation in the 1990s.

**Curriculum as Epistemic Device**

We conceptualize an alternative metaphor as *curriculum as epistemic device*, in which the primary goal of curriculum is to provoke interactions that generate understanding. In this metaphor, the role of tasks in curriculum materials is to provoke and progressively refine student thinking, individually *and* collectively, as opposed to serving as a delivery mechanism for content. This conceptualization of curriculum design builds from a notion of text as *thinking device* that promotes dialogic interaction (Wertsch & Toma, 1995).

A primary characteristic that shapes task affordances in this metaphor is the potential for heterogeneous approaches that vary in terms of their entry points and sophistication, or what has been called *low-threshold, high ceiling* tasks (Myers, Hudson, & Pausch, 2000). Myers and colleagues described software interfaces in terms of being *low-threshold and high ceiling*, meaning that the software was relatively easy to learn at a basic level but could be used to accomplish complex and difficult problems. This idea can be applied to tasks that are accessible to intuitive approaches while also allowing for the possibility of more abstract or symbolic approaches. Comparing intuitive approaches to more abstract or symbolic approaches creates opportunities for making connections that promote conceptual understanding.

Kapur and Bielaczyc provide insights into the dialogic potential or affordances that result from low-threshold, high ceiling tasks (Kapur, 2008; Kapur & Bielaczyc, 2012). Such tasks afford opportunities for students to initially attempt a problem before encountering challenges that require additional personal and collective resources. Kapur and Bielaczyc refer to the phenomenon of allowing students to reach the limit of their current resources and understanding before seeking assistance as *productive failure*. Productive failure typically entails the use of informal approaches and invented representations or over-generalized application of previous skills that are eventually contrasted with properties of more productive representations or efficient approaches, which helps students to better understand the conceptual properties of a given representation or approach. Students who were allowed to reach productive failure on complex tasks called on their individual and collective epistemic resources in ways that helped them connect their evolving mathematical understandings to more conventional and efficient representations and approaches. Students' *epistemic resources* include their intuitive forms of reasoning, their invented representations, and informal language (Hammer, Elby, Scherr, & Redish, 2005; Kapur & Bielaczyc, 2012).

The discussion above emphasizes the emergent and localized construction of knowledge that is associated with dialogic curriculum and instruction. When tasks promote interactions that generate sense-making and afford opportunities for students to draw on and coordinate their epistemic resources, local and idiosyncratic forms of knowledge are more likely to be emphasized as sense-making resources. This process has been conceptualized as *knowledge building* by Scardamalia and Bereiter (2006). They state that schools should focus on the emergent and collective development of understanding in a knowledge-building community so that student thinking is viewed in terms of its epistemic value – its ability to advance the knowledge of the community. This contrasts with the process of evaluating student thinking with respect to conventional knowledge, as is typically done in classrooms. The emergent and collective development of understanding in a knowledge-building community is facilitated when participants see how their ideas build from one another and how they are positioned with respect to more conventional or expert knowledge. Students' solutions serve as e*pistemic artifacts* (Sterelny, 2005, as cited in Scardamalia and Bereiter) that serve to advance the understanding of mathematics in the classroom community.

In summary, the metaphor of curriculum as epistemic device focuses on the dialogic affordances of tasks that offer the potential for interactions that promote understanding through their accessibility, ambiguity, and connections to big mathematical ideas. These low-threshold high-ceiling tasks allow for students to draw on their epistemic resources in ways that contribute to the collective and emergent development of mathematical understanding. This stands in contrast with the more remote authority manifest in the transmission or delivery metaphor.

In this metaphor, teachers are positioned as orchestrators of mathematical discussions (O'Connor & Michaels, 1996). In order for the dialogic affordances of tasks to be mobilized, teachers need to recognize the heterogeneous approaches and the relations between those approaches in order to support the development of dialogue around those approaches. Furthermore, teachers need to understand how student reasoning develops across instructional sequences, which stands in contrast to the much more local conception of mastery in the delivery metaphor. Similarly, students are positioned as active intellectual contributors with challenging *epistemic roles* (O'Connor & Michaels, 1993, 1996).

The development of curriculum in this metaphor departs from the technical-rational or scientific approach in the delivery metaphor. Gravemeijer (1994) describes curriculum development as integrating elements of research and design, in part by conducting design experiments that inform the development of curriculum materials. These design experiments (Cobb et al., 2003) focus on developing *local instruction theories* (Gravemeijer, 2004) that are situated within particular instructional sequences. The instructional sequences are enacted in classrooms, generating data and insights that are used to revise the sequence. This process involves intensive observations of how student thinking is elicited and refined over the sequence, positioning students as key resources not only in classroom enactments but also as dynamic agents in the design experiment. Another feature of curriculum development is the notion of *progressive formalization* (Bransford, et al., 2000) in which instruction elicits and builds from students' informal or pre-formal thinking, which is then progressively refined toward more formal mathematical representations and terminology. Gravemeijer argues that teachers' ability to recognize and build from student thinking is related to their understanding of how that thinking is situated within a broader instructional sequence.

The curriculum as epistemic device approach is based on interactions that promote sense-making or understanding, which inherently involves heterogeneous voices (Wertsch & Toma, 1995), including those based in everyday or informal language. The instructional sequences provide opportunities for this language to be revisited and revised, and a primary role of the teacher is to facilitate the process of language development. Thus, the view on language development in this metaphor contrasts sharply with the delivery metaphor.

## Conclusion

We elaborate two metaphors, in part to draw distinctions between two approaches historically evident in U.S. middle school mathematics curriculum materials but also to develop an analytic lens for looking at new materials and technologies related to the rapid and comprehensive move to digital forms of curriculum resources. In many cases, new digital materials have intensified features that follow the delivery metaphor and accompanying technical rational basis. A few prominent programs, such as Khan Academy, deliver mathematical explanations in new platforms, while others situate traditional content in learning management systems (Author, 2014). Few programs as yet provide the potential to elicit and make public student thinking in ways that utilize those approaches as epistemic devices in classrooms.

Moving forward, it will be important to analyze curriculum programs and enactments of those programs with respect to which metaphor prevails. Given the emphasis on knowledge creation in civic and economic life, it is imperative that curriculum resources and associated instructional systems help teachers recognize and build from student thinking in mathematically productive ways.

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