Designing Science Curriculum for Implementation at Scale: Considerations for Diverse and Resource-Limited Settings

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Abstract: Designers of science curricula intended for broad use must take into consideration the diversity of students, teachers, and material resources available across various settings. While curriculum design literature gives some guidance for designers, most work in this area focuses on design by small design teams working on materials for relatively narrow contexts. To further inform the work of science curriculum designers, we conducted two retrospective case studies of curricula designed for large-scale use. Qualitative data were collected through document analysis and interviews with key design team members. Data were analyzed deductively and inductively. Here we focus on findings about the influence of policy and cultural context, and the ways in which the needs of target student and teacher populations are considered during curriculum development. The findings are useful to other designers concerned with bringing science content and practices to broad audiences of diverse learners.

Keywords: science, curriculum, scale, design

Introduction

Few studies have explored processes of design and development of science curriculum materials which yield deep understanding and rich learning performance at scale. Such curricula must reflect careful attention to the wide range of human and material resources likely to be available across diverse educational settings. A wealth of literature exists that describes high-quality *outputs* of educational design, providing both theoretical and practical guidelines in the form of models, heuristics and principles (e.g. Atkinson, Derry, Renkl, & Wortham, 2000; Davis & Krajcik, 2005; Gagne, Wager, Golas, & Keller, 2004; Van Merrienboer & Kirschner, 2007). These describe abstract features of effective final teaching and learning materials. Much has also been written about the process of designing instruction (e.g. Kemp, Morrison, & Ross, 1994), courses (e.g. Piskurich, 2006; Posner & Rudnitsky, 2005; Smith & Ragan, 2004), and programs (e.g., Loucks-Horsley, Hewson, Love, & Stiles, 1998; Wiggins & McTighe, 2005). With the notable exception of Walker's deliberative approach to curriculum development (Walker, 1990), however, there is a limited empirical basis for the literature on curriculum design *processes*.

Moreover, available literature guiding educational design processes is insufficiently fine-grained for concerns of scale, which involves more than reaching many users or regions (cf. Dede, 2006). We must also examine characteristics contributing to scalability along salient dimensions. Our view of these aligns well with those of Coburn (2003), who distinguishes the following dimensions: Depth: goes beyond surface structures or procedures to alter teachers' beliefs, norms of social interaction, and pedagogy; Sustainability: the curriculum's use can be sustained in adopting schools; Spread: it can expand to more schools and classrooms, also spreading reform-related norms and pedagogical principles; and Shift in ownership: the reform becomes self-generative, under authority held by districts, schools, and teachers to sustain, spread, and deepen reform principles themselves. To achieve success on these dimensions with continued positive impacts on learners is no simple task. It requires addressing key tensions influencing the practicality and effectiveness of materials across contexts. In this study, we examine strategies and processes used by successful designers to render designs implementable across the range of real-world settings common to educational practice.

Theoretical underpinnings

The analysis presented in this paper focuses on how design teams create supports for curriculum enactment that align with their understanding of the settings, resources, and constraints likely to be present during implementation. In this study, implementation is defined as "the process of putting into practice an idea, program, or set of activities and structures new to the people attempting or expected to change" (Fullan, 2007, p. 84). It can be described as consisting of three stages (Fullan, 2007; McKenney & Reeves, 2012): *Adoption* concerns the process through which a decision is reached to move forward with a particular innovation. *Enactment* pertains to putting the innovation into practice. *Sustained maintenance* refers to actions taken to sustain the innovation under representative conditions.

Environments vary in their capacity to support the implementation of new curricula. The literature suggests a number of factors that impact capacity for implementation, including at the teacher, school, and environmental/cultural levels (Rogan & Aldous, 2005; Tao, Oliver, & Venville, 2013). Material resources include the physical condition of school facilities, library/laboratory/training facilities, consumable materials, textbooks and technological infrastructure, and exert profound influence on implementation. Similarly, the extent of human resources such as teacher capacity and administrative support, and access to networks and communities, often determine the sustained success of adoption or enactment of new approaches.

Additionally, educational settings differ along many dimensions (e.g., urban/rural/suburban, student socio-economic status (SES)), each of which has implications for curriculum implementation. For example, Fishman et al. (2011) found that the sustained use of a technology-heavy math curriculum was positively correlated with students' SES. A thorough understanding of the setting (and of the resources and constraints available) can be critical to the success of an instructional innovation.

Our work examines the design of K-12 science curricula intended for large-scale use. In this paper, we focus on the ways in which designers: (1) define the settings, resources, and constraints that will impact implementation, (2) attend to those when envisioning enactment, and (3) manifest their ideas about settings, resources, and constraints in the curriculum materials.

Methods

This study investigated the design practices that led to curricula with demonstrated evidence of success in (some of) the aforementioned scale dimensions. We asked: (1) *How did these designers define, and accommodate the settings and resources of the target users? (2) How did designers envision enactment and accordingly design supports, given their curricular goals and intended audiences?*

This data set includes projects completed at two US institutions with strong track records in curriculum design. The two cases analyzed in the current paper were: (1) a high school physics curriculum designed to highlight connections between the classroom and the workplace [pseudonym *Working Science*] and (2) an integrated science and literacy curriculum designed for grades 2-5 [pseudonym *Literary Science*]. Figure 1 provides an overview of the case selection criteria, data collection, and analysis methods.

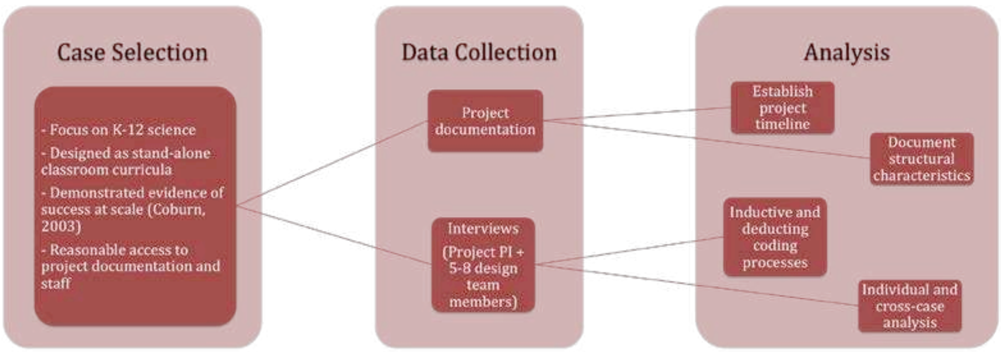

Figure 1. Methods overview.

The cases selected were each successful on two or more of these dimensions of scale: learner performance, depth of change, sustainability, spread of materials and underlying principles, or shift toward local ownership. The data set included project documentation and interviews. A wide range of document types were obtained, including grant proposals, annual and final reports to funders, evaluation reports, research reports and publications, curriculum materials (e.g., student and teacher books/guides), conference presentations, project memos, and project websites. Documents were used to develop a project profile including information about structural characteristics of the curriculum, a chronology of the design process, and the extent to which the project had achieved scale. Two rounds of structured interviews were conducted. First, an initial interview with the project PI and senior staff was held to confirm the results of document analysis. Following this, a second round of individual interviews was conducted with project designers, researchers/evaluators, and project leaders. These interviews investigated how designers considered their core intentions given various settings, resources, and constraints; how designers attend to those considerations when envisioning enactment of the curriculum; and how attention to those considerations are actually manifested in the curriculum. Data were coded deductively into project-related themes and curriculum representations. Inductive coding then looked for emergent themes in designers' responses to implementation settings and resources. After the interviews, a second round of document analysis was undertaken for the purpose of triangulating findings from participant interviews and providing additional details about events, processes, or materials described during interviews.

Findings

Settings and resources

Table 1 describes the design teams' ideas about settings and resource considerations related to implementation, and intentions for addressing these considerations. In the section that follows, we describe how those intentions were translated into enactment supports for teachers and students.

Table 1: Designers' intentions related to settings and available resources for each case.

Curriculum	Settings	Resources
Literary Science (published 2006-2011)	• Students: Designed for all students, with a focus on making materials accessible for a diverse range of students including English Language Learners. • Teachers: Designed for diverse teachers, including new teachers and those without a strong science background. Designed to be taught "out of the box" (without professional development).	• Designed to provide students with access to potentially unfamiliar environments/ ecosystems (e.g., "Can we bring the forest into the classroom?").
Working Science (published 2006)	• Students: Designed for students without a strong science/math background, not interested in traditional physics courses, and likely in vocational programs. • Teachers: Designed for teachers with a science background but likely unfamiliar with an inquiry approach.	• Designed to work in classroom with limited financial resources. • Important to provide access to community resources (i.e., workplace connections).

Enactment supports

Two themes, emerging from inductive analysis, characterized each project's approach to the development of enactment supports (see Table 2). First, curriculum development work proceeds within the larger context of education culture and policy. These two projects were responsive to the cultural pressures in place at the time of their development. Second, each project was responsive to the needs of the students in the target population.

Table 2: Themes characterizing the development of curriculum enactment supports.

Comparison Theme	Relationship to larger movements and shifts in education/policy	Accommodate needs of non-typical science students
Literary Science	*Designed to accommodate increased pressure for literacy instruction in elementary school.* • Integrated literacy-science curricula can be implemented during literacy blocks. • Teacher support materials: (1) clearly define how much time is devoted to each discipline; (2) provide educative supports for elementary teachers more accustomed to teaching literacy than science.	• Materials address the needs of English Language Learners (e.g., limiting and focusing the introduction of new science vocabulary words). • Provides teacher supports for working with English Language Learners.
Working Science	*Responsive to the 'school-to-work' movement, science standards, and to increased interest in inquiry-oriented science.* • Educative materials support teachers in guiding inquiry. • Developers questioned their ability to change teacher practice. Quotes about 'getting teachers on our side' and 'may not be possible in the scope of our work'. • Teacher materials provide explicit directions for implementation.	Students not on the "academic track" • Embodiment of unorthodox materials ("job sheets"); student resource guide instead of text. • Focus on developing shared experiences (e.g., workplace visits) for under-resourced students.

Conclusions and implications

Our analysis highlights the influence of policy and cultural context, and the ways in which the needs of target student and teacher populations are considered during the development of curriculum intended for large-scale use. The study makes several contributions to the existing literature. First, our work contributes to educational policy scholarship by exploring how two groups of curriculum designers interpreted and responded to movements and trends in education, and highlights how designers can leverage policy shifts in ways that support (rather than place demands upon) educators. Second, our analysis explores design tensions and solutions related to the creation of enactment supports for diverse learners. Future work will examine additional design projects and the specific analysis, development, and evaluation processes behind the creation of enactment supports for diverse educational contexts.

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Acknowledgments

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