Trends in the design, development, and use of digital curriculum materials

Jeffrey Choppin, University of Rochester

RC Box 270425

University of Rochester

Rochester, NY 14627

Zenon Borys, University of Rochester

RC Box 270425

University of Rochester

Rochester, NY 14627

Corresponding author: Jeffrey Choppin, [jchoppin@warner.rochester.edu](mailto:jchoppin@warner.rochester.edu), 01-585-273-4913

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Abstract

We explore questions around the design, development, and dissemination of digital curriculum materials, the perspectives in these areas, and how these perspectives align with broader discourses in education. We identify and briefly describe four perspectives: 1) designer perspective; (2) policy perspective; (3) private sector perspective (e.g., publishers and philanthropists); and (4) user (teachers and schools) perspective. We discuss how these perspectives converge and diverge by looking at the different features of curriculum materials emphasized by each perspective and the reasons for these emphases. The discussion and findings speak to the promise of digital programs as well as limitations related to the rationales related to the development, dissemination and use of digital curriculum resources. The emergence of a dominant perspective speaks to broader concerns about educational priorities being formulated according to a market-based rationality.

Keywords: Digital media, educational policy, mathematics education, curriculum

**1 Introduction**

In many countries, there are increasing pressures for schools to adopt and take up digital materials (Devaney, 2013; Kampylis et al., 2013; LEAD Commission, 2012; Selywn, 2007; Usdan & Gottheimer, 2012; U.S. Department of Education, 2016). Advocates argue that digital materials have potentially transformative features, such as enhanced interactivity, customization, and adaptive assessment. However, there are multiple forces informing the design, dissemination, and use of digital curricula that will influence the extent to which and the ways in which these transformative features will be incorporated into the development of digital materials, disseminated at scale, and taken up by users.

In this paper, we discuss four perspectives that are simultaneously constructing different discourses around the design, dissemination, and use of digital curriculum materials. We describe how these perspectives come into tension with each in terms of how they converge or diverge with respect to the features emphasized in digital materials. The tensions we identify have similarities to other discussions of conflicting perspectives in education and in the work of teachers. Labaree (1997), notably, explains how three competing goals of education in the US – democratic equality, social efficiency, and social mobility – have historically been in tension with respect to articulating educational priorities. These goals converge or diverge in terms of their focus on education as a public or private good, the role of markets, and how educational reforms or policies position people in the social order. Each perspective emphasizes particular discourses that include the “language we use to talk about schools, the ideas we use to justify their existence, and the practices we mandate in promoting their reform” (p. 43). Although these perspectives have historically maintained relatively equal weight in the creation of educational reforms and policy, Labaree points to the increasing dominance of one perspective, the social mobility goal. Labaree points out that adherents of the social mobility goal recruit “entrepreneurial language” in which educational institutions should “cater to the demands of their consumers” (p. 59) in order to prepare them for success is competitive markets.

Elsewhere, Herbst and Chazan (2011) outline four obligations that teachers manage during instructional situations: *disciplinary*, *individual*, *interpersonal*, and *institutional*. These obligations speak to how, in a given instructional situation, teachers balance considerations related to the discipline of mathematics, individual students in a class, collective norms and characteristics in a classroom, and aspects of the multiple institutional facets of schools. These obligations may align in some situations, but more often these obligations conflict in some way. Despite this, teaching in most circumstance involves stable practices, meaning that teachers have found a way to justify their actions even when these actions violate one or more of their obligations. Consequently, in reflecting on the tensions in the perspectives on digital curriculum, we consider justifications for emphasizing particular features over others.

We begin by discussing the features of digital curriculum resources touted for their transformative potential, as identified in our prior work (Choppin, Carson, Borys, Cerosaletti, & Gillis, 2014). After we discuss the methodology for our survey of the literature in Section 3, in Section 4 we discuss how we identified the four perspectives around which we base our analysis. We explore how the features emphasized in each perspective entail different resource requirements and different potential to develop capacity, which has implications for resource allocations and long-term development of the teaching force.

**2 Potentially transformative aspects of digital curriculum resources**

Digital curriculum resources are touted as having features different from hard copy texts (cf. Abell, 2006; Fletcher et al., 2012; Selwyn, 2007; Zhao, Zhang, & Lai, 2010), with advocates reporting the potential for greater interactivity, greater individualization and customization, increased and varied social interactions, lower cost and greater accessibility, and assessments systems embedded that can make digital materials more adaptive and assessment data more actionable.

Based on a prior study in which we analyzed eight digital curriculum programs (Choppin et al., 2014), we identified features that were most frequently raised in regards to these and other digital programs. We briefly explore four claims related to the features of digital programs that are potentially transformative and explore the ways these features are emphasized by different stakeholders. Digital resources:

* afford transformative learning experiences;
* provide access to high-quality and freely available materials;
* facilitate customizability or individualization of content; and
* include embedded assessment systems that adapt programs to the needs of the learner.

Advocates claim that digital materials have the potential to transform learning experiences for students by being more relevant and interactive. Digital content can be updated and revised to fit the local context, making it more relevant to students (USDOE, 2016; Fletcher et al., 2012). In terms of interactivity, digital texts can be flexible with respect to navigation (e.g., hyperlinks) (Kraidy, 2002) and with respect to creating documents with resources and materials from a range of sources, including the web (Zhao et al., 2002). More powerful forms of interactivity involve the use of tools with flexible purposes in open working environments, such as curriculum programs developed in Israel and Korea (cf. Lew, 2016; Yerushalmy, 2016). In general, interactivity can be conceived in terms of the choices users can make to influence the flow and nature of the content (Zhao et al.)

The second claims relate to Open Education Resources (OER). Advocates claim that freely available digital content can make high-quality content accessible to low-resource schools. Internationally, there has been a push for OER for nearly a decade now: “The open educational resource (OER) movement aims to break down such barriers [from proprietary systems] and to encourage and enable freely sharing content” (Organisation for Economic Co-operation and Development [OECD], 2007). Recently, the US Department of Education launched an initiative designed to encourage districts to adopt open resources and to share their efforts and experiences with others, in part to make access to high-quality instructional resources more equitable (USDoE, 2016). A second claim related to OER is that digital content can be made adaptable to fit the needs of local schools (Yettick, 2016a).

A third claim is that digital content can be customized to meet the needs of individual learners. Customization has been discussed in a variety of ways. First, it can be achieved through systems that emphasize mastery learning, in which software dictates the sequencing of content based on the learner’s performance on skills-based assessments (e.g., Means, Peters, & Zheng, 2014). Second, it could involve personalizing the software settings so that the user has control over video and audio as well as the presentation of the text (Abell, 2006) in ways that follow the principles of Universal Design for Learning (Meyer & Rose, 2000). A third way is for the teacher to make content selections within a program so that different students would see different content (Choppin et al., 2014).

The last claim relates to assessment systems embedded in digital programs. Digital materials embed assessment systems that provide rapid feedback to users and that provide data reporting of performance to a variety of stakeholders. These systems can be geared to customize content for the learner, providing additional prompts or support or they can be geared toward the teacher, so that instruction can be adapted based on performance (Abell, 2006; Fletcher et al., 2012).

**3 Methodology**

**3.1 Research questions**

We used the following research questions to guide our work:

1. Who are the different entities involved in designing, developing, and disseminating digital curriculum materials?
2. What features or purposes of digital materials are emphasized by these different entities?
3. What perspectives are evident in the purposes stated for the design and development of digital materials, and how do these perspectives align with broader discourses on education?

**3.2 Survey methods**

We conducted a survey of literature on the design and use of digital curriculum resources in school mathematics classrooms. Using primary keywords such as ‘digital curriculum’ or ‘digital resources,’ we searched various databases, such as Google Scholar and academic databases. Over a two-year span, we regularly perused the practitioner literature (e.g., Education Week, Smartbriefs), which often led us to other reports, such as reports or evaluations and other media reports. We subscribed to Market Briefs for a year, which provided access to proprietary surveys of key school personnel around the issues of technology, digital curricula, and open education resources. We analyzed chapters from the book *Digital Curricula in School Mathematics* (Bates & Usiskin, 2016) which constituted a current overview of international projects in digital curricula in school mathematics education.

We identified 34 sources from which we based our survey of the literature on digital curricula in school mathematics. Of these, 22 were empirical sources, with the others being policy documents (4), analyses of policies (3), descriptions of designs of digital curricula (4), and an article based on an interview. In terms of the breakdown by each perspective, there were six articles based on the designer perspective, nine from the policy perspective, 12 from the user perspective, five from the private sector perspective, and two from multiple perspectives. Table 1, where we categorize sources by type, shows that over a third of our sources were from the practitioner literature and nearly a third from peer-reviewed journal articles.

Table 1

*Number of Sources by Type*

|  |  |
| --- | --- |
| Type | Number |
| Practitioner literature (e.g., Education Week, Market Brief, eNews) | 12 |
| Chapters from *Digital Curricula in School Mathematics* | 4 |
| Policy documents (OECD, UNESCO, USDoE) | 4 |
| Reports or evaluations | 3 |
| Peer-reviewed journal articles | 10 |
| Book | 1 |

**3.3 Identifying and analyzing perspectives**

To identify the perspectives, we initially made distinctions in terms of producers and users of digital curricula, as we felt these two groups balanced different and perhaps competing commitments. We then divided the producers by their primary rationales for developing digital curricula. One rationale was market-based and the other was design-based. The market-based perspective, or private sector perspective, included commercial publishers whose primary goal is to satisfy perceived desires of consumers. The designer perspective involved people who designed their programs based on research on teaching and learning. A fourth group we identified were policy makers, who have commitments distinct from producers and users. A fifth group emerged during the review of literature, that of corporate-based philanthropies such as the Gates Foundation. We folded this group into the private sector view to signify the market-based discourse they employed to emphasize digital curriculum programs.

**3.4 Tying perspectives to features**

We focused on the features emphasized in each perspective and the reasons for emphasis to unpack assumptions about the purposes ascribed to digital programs. We searched sources associated with each perspective and identified the frequently mentioned features. We characterized the discourses employed to justify that features such as: easing demands on teachers and administrators, especially in regard to customizing or individualing instruction; creating more challenging and interactive learning experiences; or making high quality resources more accessible to all students. We then considered how these discourses were compatible with each other or were in tension with each other, and the kinds of resource or capacity commitments entailed by these features.

**4 Perspectives on the design, development, and use of digital curriculum materials**

**4.1 Designer perspective**

We refer to designers as those who conceptualize features of digital materials based on research on learning and learning systems. Designers emphasize the transformative aspects of digital materials, in terms of creating texts and learning experiences that augment or enhance what is possible in paper curricula. First, designers aim to create complex and rich experiences, ubiquitous access to tools, workspaces that incorporate tools and dynamically linked representations, and the ability to record and curate work (Confrey, 2016; Edson, 2016; Lew, 2016; Yerushalmy, 2016). Confrey, Lew, and Yerushalmy emphasize that workspaces should provide access to a suite of tools that learners strategically select as they engage in complex problems. These workspaces should facilitate the use and manipulation of multiple representations, including symbols, in ways that are intuitive and that communicate increasingly formal inscriptions of the mathematics. Furthermore, these workspaces should allow students to store and curate their work, for future reference for themselves and external audiences.

An important tension in the design of digital materials is the demarcation and flow of mathematical activity (Confrey, 2016). Curriculum materials differ from open tools, such as Sketchpad, Cabri, or Mathematica, in that they are intended to provide structure by bounding and sequencing mathematical activity. Integrating rich problems and work spaces provides opportunities for the kind of complex activity that involves non-linear processes (unproductive approaches may precede more productive approaches), complex interactions of tools and representations, and the collective negotiation of the viability and validity of solution paths. Such complex activity can disrupt well-defined lesson structures and allocations of time (both duration and synchronicity)(c.f. Ritella & Hakkarainen’s (2012) discussion of chronotype), interrupting the potential flow of a lesson, with implications for following a prescribed scope and sequence of mathematics.

Another important tension is the balance between individual work that engages important psychological processes (e.g., *flow*, as described in self-determination theory) and collective work that emphasizes the role of interaction in the learning of mathematics. Confrey (2016) explains that designing workspaces that emphasize and enhance the collective aspects of mathematical activity is essential. This requires workspaces that allow for collective work (e.g., electronic documents that can be simultaneously viewed and edited by multiple authors) as well as the ability to communicate to external audiences, such as group members, the teacher, or other members of the class. The emphasis on these features is in tension with features that provide support and scaffolds aimed at facilitating the competencies and tendencies of students engaged in individual work.

In sum, the design perspective emphasizes tensions in how to create accessible, flexible, and tool-rich workspaces that accommodates the needs of individuals while also enabling collective aspects of mathematical activity. This perspective builds from theoretical and empirical research based in the learning sciences and sociocultural paradigms that emphasize the importance of tools, representations, flexibility, language, and processes (as opposed to inherent and universal characteristics) (Cole & Engeström, 1993; Wertsch, 1991). These features require considerable capacity on the part of teachers, as they are expected to coordinate the collective discussion of diverse approaches that emerge from the learning activities; furthermore, these learning activities take place in complex and flexible environments, lending themselves to idiosyncratic and non-canonical approaches and use of representations.

Another type of designer-based effort is to curate content, in which content is organized and vetted by an entity different from those who create the content. A type of curation from the designers’ perspective involves researchers evaluating material on the internet and situating the material within a learning trajectory, so that users can pick content according to a research-identified trajectory (Confrey, 2016). This is intended to offload much of the work of selecting and sequencing activities and designing assessments, reducing the need for teachers to conduct time-consuming search and evaluation of content, while preserving the potential for teachers to develop the capacity to engage in responsive forms of instruction.

**4.2 Private sector perspective**

We defined a private sector perspective as deriving from corporations or organizations that create digital content with a consumer in mind, rather than from the perspective of research on learning and teaching. These products are designed to appeal to consumers (e.g., administrators, teachers) by claiming to ease instructional and assessment demands or to improve management practices (Burch & Good, 2014).

We identified four distinct trends related to features in digital curriculum materials emerging from the private sector perspective. The first trend is to embed digital content in comprehensive learning management systems that include data reporting and classroom management systems. The second trend is an emphasis on adaptive programs based largely from the mastery learning perspective. The third trend involves collections of lessons or content developed by small author teams, some by for-profit corporations and others by non-profit entities that use market-oriented or entrepreneurial discourses in their promotional materials. The fourth trend is a private sector version of curated content where a person or bot is used to select and organize content developed on the web and freely available. These four trends have substantive overlaps in some instances, but are distinct enough that we devote separate sections to discuss them.

The first two trends have been marked by the presence of commercial publishers, media corporations, and philanthropic entities that develop and encourage the use of digital content. Some of these entities emphasize personalization via adaptive software, incorporating activities based largely on the mastery learning perspective, while others are generating or plan to generate repositories of open resource content, some of which is then embedded in a proprietary system that emphasizes personalization and adaptive assessment. These efforts are described in more detail below.

Large commercial education publishers, such as Pearson and McGraw-Hill, have primarily emphasized placing their existing content within comprehensive learning management systems that incorporate content management, assessment, and management software (Choppin et al., 2014). They advertise the potential for adaptive content in two ways. One, they incorporate features that allow teachers the flexibility to sequence content and select resources from within the program to modify the content offered to students. Two, they promise adaptive assessment systems that track students via embedded assessments and then assign content to students based on results. McGraw Hill Education (<http://www.mheducation.com/>, accessed 03/01/2016), for example, advertises features such as adaptive assessment, individualization, and rapid assessment and evaluation of student progress.

Similarly, Pearson advertises their fully digital program ***digits*** (Fennell et al., 2014) as a “one of a kind program that will keep learners motivated using technology to provide them with individualized learning paths and self-guided exploration options,” stating further that “readiness assessment and auto-scored homework immediately identify students’ understanding of content so that you can focus on individual needs during class” (<http://www.pearsonschool.com/>, accessed 03/02/2016).

Research on the design and use of these programs suggests that the features are still in early stages of development and have not been taken up by users. An analysis two years ago of CINCH, a current McGraw-Hill fully digital product, showed that while a range of features was advertised, their functionality was primarily geared toward data reporting and classroom management (Choppin, 2016). Furthermore, an empirical study of teachers using ***digits*** showed that teachers did not mention the embedded assessment features, with the primary use of the program being that teachers drew from the collection of video-recorded presentations to introduce topics mathematical topics and procedures (Choppin & Borys, 2016).

The second kind of digital programs developed from the private sector perspective are adaptive programs, usually based on a mastery perspective where learners progress through content via a series of embedded assessments. The Gates Foundation and other foundations advocate for customized learning associated with assessment systems, as evidenced by the Gates Foundation-funded Next Generation Learning Challenges grant competition, which emphasizes, among other things, “personalized learning” and “real-time analysis” (<http://nextgenlearning.org>, accessed on 06/18/2016).

While companies and philanthropic organizations have touted the potential of adaptive features, the results in practice have been modest. A number of studies funded by the Gates Foundation and other foundations have focused on the impact of adaptive courseware in mathematics education, albeit in higher education settings (Feldstein, 2016; Means, Peters, & Zheng, 2014; Yarnell, Means, & Wetzel, 2016). Many of the programs involved a mastery learning perspective in which students had to complete an assessment at a certain level of accuracy before they were allowed to proceed to a new topic. The studies linked the mastery learning perspective and automated feedback with an emphasis on personalization. The implementation of the mastery learning modules led to tensions between the pace of completion of content and the depth of learning. At times, mastery learning hindered completion when demands were too stringent. Other innovative features related to personalized learning did not produce noticeable outcomes (Means, Peters, & Zheng, 2014).

Mark Zuckerberg’s philanthropic and investment actions similarly emphasize customized learning approaches. He has already invested in a number of for-profit educational companies (Herold, 2016), and his philanthropic efforts emphasize *self-guided learning paths* tailored to individual needs and an emphasis on competency-based education. In the competency-based education, the focus is on mastering specific skills rather than completion of courses, with students progressing through a self-guided learning path where their progress is tracked via adaptive software (Herold, 2016).

The third type of private sector program involves collections of lessons or content, sometimes developed by a small group or by larger author groups, often teachers who are contracted by the organizing entity or who volunteer to contribute lessons. In each of these collections, there is no opportunity for the teacher or instructor to author new content or revise existing content. Instead, the user (student or class of students) can view a presentation on a particular topic. Usually there are practice problems and assessment problems associated with the presentation. One such program is Khan Academy, which features a collection of video-recorded explanations of mathematical concepts. Khan Academy also includes assessment features, though the assessment results are used as guidance for the instructor or user to select new content rather than having the program automatically select new content, as would be the case in a fully adaptive system (Choppin et al., 2014). Furthermore, Khan Academy provides information on the videos viewed by a user, which is then sent to either a parent or a teacher. Recently sofatutor.com published a similar collection of video-recorded presentations for Algebra, and other efforts are likely to crop up that mirror Khan Academy’s model.

There are other collections of digital lessons, and instead of being developed by a relatively confined team such as at Khan Academy or sofatutor.com, these are developed by a group of authors who are each responsible for a small set of lessons and who narrate the presentations. LearnZillion and YourTeacher provide sets of videotaped explanations or demonstrations for students to watch. The content can be situated within a larger learning management system that includes worksheets and assessments. In LearnZillion, teachers may assign topics to students based on performance on embedded assessments; YourTeacher makes suggestions for content based on student test scores (Choppin et al., 2014).

The fourth type of effort from the private sector perspective involves curated content. As noted above, curated content is typically organized and vetted by an entity different from those who create the content. There is variation in how content gets curated from the private sector perspective. In the case of OpenED, there is a bot that searches the web for content, which is then vetted by subject area experts (<https://www.opened.com/>). Gooru follows a similar model: a small set of educators curate content for personalized learning. These educators curate selected materials, which are embedded in an online assessment and curriculum resource site. The site advertises a blend of “powerful assessments and analytics with a catalogue of learning resources to help teachers track student progress and understanding and meet the needs of every student.” (<http://www.gooru.org/welcome/>) (Molnar, 2016). Gooru, a non-profit, has its roots in corporate philanthropy and venture capital, as evidenced by its founders, board, and content partners.

In an analysis of trends in digital education in the K-12 US context, Burch and Good (2014) noted that one effect of adopting digital curricula is that in many instances schools lose control over the content in the program and thus the curricula encountered by their students. When schools contract with commercial entities to deliver content embedded in management systems, the content is effectively determined by the vendor, not the school that purchases the curriculum. Furthermore, Burch and Good point out that the vendor has little motivation to spend money to develop high-quality content, and that as a result, the content in many digital curriculum programs is low-quality. In addition, while much of the discourse used to sell these curriculum programs is focused on creating more equitable learning opportunities for students in low-income schools, analysis of the implementation of these programs has uncovered a myriad of problems and poor overall quality.

Efforts from the private sector perspective have encountered other strong critiques. Echoing Burch and Good (2014), Saltman (2016) points to large philanthropic efforts – such as those of the Gates Foundation, the Walton Foundation, the Broad Foundation, and Zuckerberg – as pushing to privatize public education and to create digital products aligned with the de-professionalization of teachers more generally. The teacher’s role in adaptive or personalized settings becomes more prescribed and limited, trumping teachers’ decision making. Furthermore, Saltman reports that many of these efforts fail because they are tone-deaf to the interests and needs of teachers and students, reflecting the private sector view to create content based on perceived views of market demands in order to increase the pool of users. In addition, the impact on privacy is a concern, as these programs use data in ways that may not serve the interests of the students.

In terms of looking at the likely resource allocations and development of teacher capacity associated with the private sector perspective, many of the features proposed by this sector involve costly allocations of resources, such as the purchasing of curriculum programs and associated management systems, while simultaneously providing little potential for the development of teacher capacity.

**4.3 Policy perspective**

We associate the policy perspective with attempts by government entities to encourage the design, development, and use of digital curriculum resources. There is strong policy push to adopt digital materials. As noted above, policymakers in the US, UK, and Korea have called for the adoption of digital curriculum textbooks. Reasons cited in policy documents include the lower cost of digital textbooks, the ability to customize content, and the ability to constantly update digital material to reflect technological innovations and contemporary content.

Internationally, there has been a push for OER for nearly a decade now (OECD, 2007), with the goal of freely using or repurposing high-quality content. Similarly, in 2012 UNESCO requested nations to encourage and enable the use and development of OER (UNESCO, 2012). Given the strong policy push to use OER, it is important problematize and contextualize the development and use of OER. Toumi (2012) provides important an important contextualization of the use and development of OER and related policy positions, situating them in larger technological and educational transformations. Toumi described a continuum of four stages in OER development.  The first level is focused on openness and access (e.g. access to a textbook).  OER II is focused on the right to access and enjoy services generated by the resource.  MIT’s open courseware is an example.  Access is universal (depending on internet connection), but there is no recognition of learning. OER III adds users’ rights and capability to modify resources to add value. Tuomi (2013) used just-in-time personalized learning as an example.  OER IV has the capabilities of OER III, but with the added caveat of newly improved resources can be redistributed.  Consumers become producers and the focus is on collective generation of resources.  MIT’s *scratch* (kid’s programming language) is an example because users can download other users’ programs and remix them for their own purposes, and then share those programs. Thus, OER involves multiple levels of resources, each with different implications for development, use, and dissemination.

In addition to the policy push for OER, the US Department of Education recently initiated a policy – the #GoOpen initiative – for schools to adopt OER as a means of replacing hardcopy textbooks (<http://tech.ed.gov/open-education/>), with an explicit goal of increasing access for all students to high-quality content. This policy was related to the ConnectED initiative, which is designed to get all schools connected with high bandwidth internet. The US DOE recruited 10 districts to serve as “ambassadors” for the #GoOpen initiative by adopting open content and sharing their experiences with other schools (Molnar, 2016).

More recently, the US Department of Education (2016), called for educational technology companies to expand and improve the use of learning, or data, dashboards, in a bid to increase the data-driven nature of instruction. The 2016 National Educational Technology Plan from the USDOE emphasized the use of data systems, particularly data dashboards that provide “timely and actionable feedback about student learning” by tracking, reporting, and communicating assessment results to a variety of stakeholders (US Department of Education, 2016). In practice, the implementation of dashboards can be messy. A school district in the southern US used a dashboard system for a year and a half, but ran into trouble when teachers began using providers who had not integrated their content into the system, forcing the district to temporarily halt its use (Herman, 2016). Similarly, having access to multiple students’ screens provides teachers with potentially insightful assessment opportunities, but the sheer quantity and novelty of data overwhelms teachers (Clark-Wilson, 2010).

More broadly, the use of digital programs reflects evolving policy trends that impact the role of textbooks or curriculum programs as the primary means of defining curriculum. The continuing emergence of the use of political documents and high-stakes assessments – such as the high-stakes assessments based on the Common Core State Standards – as the primary means of articulating curriculum (Chazan & Yerushalmy, 2014) potentially leads to de-emphasis of curriculum programs as the primary providers of curriculum content. Furthermore, these policies, combined with the intensifying pressure to adopt digital solutions to educational problems, has the impact of destabilizing school structures, providing opportunities for vendors to gain access to school markets (Burch & Good, 2014).

In terms of looking at the likely resource allocations and development of teacher capacity associated from the policy perspective, the emphasis on OER ostensibly involves minimal resource allocations (it is freely available) but requires high capacity in terms of selecting high quality content and sequencing it to make a coherent curriculum. At the same time, OER materials are of uneven quality, minimizing the potential for the development of teacher capacity. Other features emphasized by policy makers, such as the use of data dashboard and digital curriculum programs involve high resource commitments while simultaneously offering little potential for the development of teacher capacity, as the primary aim is to offload instructional decisions onto the programs.

**4.4 User perspective**

We conceive of the user perspective in terms of those who implement digital curricula in their schools or classrooms. While there is no single user perspective, it is clear that users are pragmatic in how they seek and take up digital materials, suggesting that they perceive different needs with respect to digital curriculum programs than those emphasized in the other perspectives.

School administrators and instructional leaders indicated in several surveys that the most often cited benefit needs related to digital curriculum content was the ability to personalize or differentiate curriculum (Digital Content Goes to School, 2016), especially to remediate struggling students (Yettick, 2016c). Related to this perceived benefit, school administrators and instructional leaders also stated that a desired feature was the ability to track and communicate progress to students and parents, and to incorporate features that would adapt content based on student performance data (Yettick, 2016b). These desired features are not surprisingly those targeted by commercial vendors. Other benefits mentioned by school or district administrators were greater engagement (Digital Content Goes to School, 2016) and technology that allowed for varied types of instruction (Yettick, 2016b).

Teachers expressed different interests or needs, reporting certain features they wished to be incorporated into the design of digital curriculum materials. First, they wanted the technology to be relatively easy for students to use without a lot of explicit or additional instruction (Hanson & Carlson, 2005; Kasten & Sinclair, 2009). Teachers felt that digital resources were useful and a potential time-saver but, they also felt they did not have the time to learn how to incorporate resources (Hanson & Carlson, 2005). In general, teachers seemed to see the process of developing students’ ability to use digital resources as a separate goal from their curricular goals and wanted to minimize time spent pursuing it (Hanson & Carlson, 2005; Kasten & Sinclair, 2009). Second, teachers wanted resources that are already aligned with their current curriculum (Kasten & Sinclair, 2009). When teachers adopt complex digital resources (e.g. dynamic geometry software or digital math environments), teachers appropriate them in ways that align to their prior instructional practices (Drijvers, Tacoma, Besamusca, Doorman, & Boon, 2013).

Related to OER, the interest of school administrators was focused on affordability and flexibility, with a view that teachers could select lessons and units as needed to fit their curricular needs. In a survey of district leaders, a majority (roughly three fourths) stated that their primary interest in open educational resources was that they would be more adaptable or able to be repurposed for district needs (Yettick, 2016a). Similarly, teachers preferred digital resources designed as small lesson segments (Clark-Wilson, Hoyles, Noss, Vahey, & Roschelle, 2014). Such flexibility fits into plans for schools that adopt systems such as Edmodo or Schoology, which are independent from curriculum content. As these content-independent learning management systems are adopted, schools seek open resource or modular curriculum materials, not the comprehensive packages offered by major publishers.

Teachers in the US are already turning to OER in significant numbers. One third of teacher respondents in a survey conducted by the Center for Education Policy Research stated that they had used EngageNY, an OER, to find materials aligned with the Common Core Standards (Heitin, 2016a). Similarly, a third of teachers stated that they had used or adapted lessons from LearnZillion, another free online resource, to create lessons aligned with the Common Core Standards (Heitin, 2016a). A RAND survey of 1,100 math and ELA teachers found that 44% of elementary teachers and 30% of secondary teachers from states using the Common Core Standards used EngageNY materials (Heitin, 2016b).

Despite the promise of OER or other digital resources, there are concerns related to costs and capacity. Administrators, teachers, and instructional leaders reported that affordability and bandwidth were top concerns in their purchases of digital content, in addition to students’ home access to the content (Yettick & Reimer, 2016). There have been considerable implementation challenges when schools have turned to purely digital curriculum resources, especially around the issue of bandwidth and student access at home (Saltman, 2016).

In terms of resource commitments and capacity related to desired features of digital curricula, there are mixed results from the user perspective. Administrators seek affordable and flexible resources in terms of customizing content, while at the same time wanting programs that help support efforts to remediate students who are struggling. Teachers want resources that fit into their current systems and practices, while at the same time they want resources that are compatible with new state curriculum frameworks. The current resources commitments, however, have often failed to keep up with the demands of digital curriculum programs, such as bandwidth and access, suggesting that greater resource allocations may be needed. In terms of the potential to develop capacity, OER will require that teachers become proficient at evaluating curriculum resources and sequencing content. Given the right support, this would help teachers develop capacity; without the right support, this will require extra demands on teachers for which they are not prepared.

Table 2 summarizes the four perspectives, the features each emphasizes, and implications in terms of resources commitment and the development of teacher capacity.

Table 2

Tensions between perspectives in terms of design features and teacher capacity

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Emphasis and impact | Perspectives on design and dissemination of resources | | | |
|  | Designers | Private Sector Entities | Policy Makers | Users |
| Features emphasized | Highly interactive; strong emphasis on collective interactions; rich tasks | Adaptive assessment; individualized learning; learning management systems | Open education resources; individualized or customized learning | Resources that reduce administrative and management demands; Resources that fit into existing practices and systems |
| Discourses used to justify features | Research on teaching and learning | Market-based discourses; managerial efficiency | Access; individualization and customization | Pragmatic; managerial efficiency |
| Resource requirements and potential to develop capacity related to features | High resource commitment; high potential to develop capacity | High resource commitment; low potential to develop capacity | For OER, low resource commitment; moderate potential to develop capacity | Mixed potential for high resource commitment; Mixed potential to develop capacity |

**5 Tensions in perspectives**

The results show are competing demands and discourses related to the development, dissemination, and use of digital curriculum programs, with implications for what features are likely to be available in classrooms and how transformative those features may be with respect to students’ opportunities to learn mathematics. The perspectives highlight the complexity of the digital space, and the potential for the space to become dominated by a limited range of discourses in ways similar to that described by Labaree (1997). Furthermore, the user perspective, where the promise of digital resources collides with pragmatic and logistical considerations, illustrates how, in managing multiple obligations, practitioners privilege some obligations over others in an attempt to maintain a viable and stable pedagogical space, similar to what Herbst and Chazan (2011) observed. These themes are explained in more detail below.

Neo-liberal perspectives (cf. de Alba et al., 2000) are evident in the private sector and policy persives. The neo-liberal perspective emphasizes a market-based rationale, with its focus on managerial efficiency and competition. Competition refers to the ability of users (consumers) to make rational choices regarding the selection of curriculum materials. In the case of digital curriculum materials, a focus on managerial efficiency manifests in the form of adaptive assessment, data dashboards, and individualization. In addition, the assumption that schools and teachers will be flexible with respect to the selection of curriculum materials speaks to the optimism regarding the impact of OER. Policy makers and private sector entities use the discourses of efficiency and choice to push for comprehensive data management systems and thus vendors who sell them. Furthermore, in the case of OER, the discourse of choice and flexibility masks costs related to the time and capacity requirements necessary to evaluate and sequence content.

There are tensions, however, between the private sector and policy perspectives. The policy emphasis on open resources, for example, encourages the use of activities or content from multiple sources: this ‘foraging’ behavior gravitates against the adoption of comprehensive programs developed by large publishers. Furthermore, the emphasis on OER undercuts commercial content, though there are commercial efforts to curate OER.

The user perspective is associated with aspects of the neoliberal perspective, such as the focus on managerial efficiency and desire to have choice and flexibility with respect to content (i.e., actively engage in market-based practices). However, their interests are not entirely motivated by market-based rationale for their schools or students. The user perspective also manifests pragmatic concerns related to compliance to policy mandates (e.g., standards and high-stakes assessments) and to ensuring that all students’ needs are met. The balancing of competing obligations is seen by a focus on meeting daily challenges of managing complex instructional systems in a climate of accountability. Administrators, for example, favor flexible and customizable content, especially with respect to tracking and remediating struggling students. These features are privileged over others, such as activities that involve complex problems and flexible mathematical tools in collective spaces as featured in the designers’ perspective. Thus, administrators’ obligations toward providing opportunities to develop skills important in the contemporary workplace are sidetracked by a focus on compliance issues related to addressing the needs of all students. In Labaree’s (1997) terms, administrators are managing tensions between the goals of social mobility and social efficiency. Similarly, teachers favor features that do little to disrupt their current practices, preferring stability over changes that might transform learning opportunities in their classrooms.

Features emphasized by some perspectives ignored the needs of teachers, and even reduced the roles of teachers. One implication from the kinds of features being pushed by policymakers, commercial publishers, and philanthropies like the Gates Foundation is that digital materials perform instructional and assessment functions typically under the purview of the teacher. The private sector perspective largely emphasizes a mastery learning design, with embedded assessment systems used to evaluate performance and determine access to new content. These programs narrow the role of the teacher by removing responsibilities related to assessment, replacing these complex activities with software that ostensibly can diagnose with greater efficiency and accuracy. The underlying economics of devolving such responsibilities to digital programs involves a shift in money from personnel to software, with implications for the professional lives of teachers. Furthermore, current efforts that attempt to do this ultimately disadvantage students already disadvantaged (Burch & Good, 2014).

The design features mentioned by Confrey and other designers, especially the most innovative and research-based features, are largely absent in the other perspectives. This reflects the designers’ focus on using affordances in digital spaces to create rich learning experiences, informed by research on teaching and learning. Designers’ primary obligation is to the learner and to creating instructional tasks that are accessible to a wide range of approaches, and thus a wide range of learners. Furthermore, curriculum programs developed from the designer perspective provide access to the kinds of complex and collaborative work environments that align with the most valued skills and professions in the workplace. In terms of educational priorities, then, development and dissemination of such programs would seem a priority. Yet, current sources of funding for the development of digital curriculum materials, combined with the pragmatic rather than transformative agenda of end users, is cause for skepticism with regard to the large scale development and dissemination of imaginative and transformational curriculum materials. Without such transformative efforts, there is likely to be stasis in the current inequitable distribution in opportunities to learn (Burch & Good, 2014).

The emphasis on open resources, especially in the policy perspective, entails the need for local education agencies (schools and districts) to engage in curriculum decision-making that entails an understanding of curriculum that has traditionally been in the domain of designers and publishers. Research shows that teachers struggle to build coherence in their curriculum efforts (Gueudet, Pepin, & Trouche, 2013), which illustrates potential shortcomings in assumptions of teacher capacity to productively use OER. The implication of the tension between these perspectives is that, while the private sector perspective emphasizes materials or programs that de-skill teachers, the policy perspective is pushing the use of OER, which requires considerable capacity of teachers related to curriculum processes.

An example of the lack of alignment between the policy and user perspectives is the case of a public-private partnership in Sweden. Course Hub was site developed via a public-private partnership in Sweden to serve as a repository for education resources and lessons for teachers. Yet, practicing teachers did not utilize the resource because the site was designed from a technical perspective, not that of teachers and learners (CERI, 2009). The materials on the site were not easily adaptable to teachers’ local contexts. These results affirm Saltman’s (2016) criticisms of policies as being tone deaf to the needs of teachers, affecting how digital curriculum resources are taken up at scale.

**6 Conclusions**

The tensions in the perspectives implicate potential challenges with the continuing development, dissemination, and use of digital curriculum resources. The neo-liberal perspective, dominant in the policy and private sector perspectives, emphasizes market-based features such as managerial efficiency and choice over other features that involve learning experiences that could provide broad access to a range of complex and desired skills. The presence of large commercial publishers and philanthropic organizations is likely to skew which features are available to large numbers of users, and to indicate a prevailing view of educational priorities. The literature surveyed for this study, furthermore, shows that when digital programs are enacted, particularly those developed from the private sector perspective, the results are tepid, in part because the content is low-level and in part because the programs do not engage learners. Consequently, programs developed using market-based rationales will do little to change the current prioritization of social mobility over other goals. Educators thus need to carefully consider both the empirical basis for claims regarding digital curricula and the perspectives embedded in such claims.

The focus on OER provides critical insights into how tensions in the perspectives play out, with implications in terms of the articulation of educational priorities. The evolution of OER will be an increasingly dominant feature of the development, use, and dissemination of digital curriculum materials (Toumi, 2013). The policy and user perspectives emphasize market-based rationalities of choice and efficiencies related to both curriculum flexibility and costs. However, the resourced-challenged schools are most likely to rely on OER; furthermore, doing so is likely to impact both the quality and coherence of curriculum offered to students. This leads to an unintended outcome that the use of OER is unlikely to equalize access to high-quality curriculum.

Looking forward, we briefly suggest a framework for studying digital curriculum materials. We propose five dimensions to consider: features, audience, rationale, dissemination vehicle, and resource commitments. First, developers are going to place their bets on a limited set of features, foregrounding some and backgrounding others. Second, the features are going to be pitched toward a particular audience, including possibly learners, teachers, administrators, or other stakeholders. Third, the rationale provided for prioritizing certain features provides insights into broader educational priorities in play. Fourth, large commercial entities and philanthropies are likely to hold undue influence on the breadth of dissemination of materials, while more specialized designer efforts are unlikely to have resources to advertise and disseminate their materials. Fifth, it is important to consider the kinds of resource commitments and capacity that are required to enact digital programs.

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**References**

Abell, M. (2006). Individualizing learning using intelligent technology and universally designed curriculum. *Journal of Technology, Learning, and Assessment*, 5(3), 21.

Burch, P., & Good, A. (2014). *Equal scrutiny: Privatization and accountability in digital education*. Cambridge, MA: Harvard Education Press.

Centre for Education, Research, & Innovation. (2009). Country Case Study Report On Sweden in *Beyond Textbooks : Digital Learning Resources as Systemic Innovation in the Nordic Countries*. Paris: OECD.

Chazan, D. & Yerushalmy, M. (2014). The future of mathematics textbooks: Ramifications of technological change. In Stocchetti, M. (Ed.), *Media and Education in the Digital Age: Concepts, Assessments, and Subversions*, p. 63-78. New York: Peter Lang

Chesné, J. F., Coulange, L., Grapin, N., & Le Yaouanq, M. H. *Hélice 6ème. Mathématiques programme 2009. édition spéciale pour le professeur*.

Choppin, J. (2016). Analysis of eight digital curriculum programs. In M. Bates & Z. Usiskin (Eds.), *Digital Curricula in School Mathematics* (pp. 161-176). Charlotte, NC: Information Age Publishing.

Choppin, J., & Borys, Z. (2016). *Trends in the design, development, and use of digital curriculum materials*. Paper presented at the 2016 American Educational Research Association Annual Meeting, Washington, D.C.

Choppin, J., Carson, C., Borys, Z., Cerosaletti, C., & Gillis, R. (2014). A typology for analyzing digital curricula in mathematics education. *International Journal of Education in Mathematics, Science, and Technology, 2*(1), 11-25.

Clark-Wilson, A. (2010). Emergent pedagogies and the changing role of the teacher in the TI-Nspire Navigator-networked mathematics classroom. *ZDM Mathematics Education*, *42*(7), 747-761.

Clark-Wilson, A., Hoyles, C., Noss, R., Vahey, P., & Roschelle, J. (2014). Scaling a technology-based innovation: windows on the evolution of mathematics teachers’ practices. *ZDM Mathematics Education, 47*(1), 79-92. doi:10.1007/s11858-014-0635-6

Cole, M., & Engeström. Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognition: Psychological and educational considerations* (pp. 1-46). London: Cambridge University Press.

Confrey, J. (2016). Designing curriculum for digital middle grades mathematics: Personalized learning ecologies. In M. Bates & Z. Usiskin (Eds.), *Digital Curricula in School Mathematics* (pp. 7-33). Charlotte, NC: Information Age Publishing.

Daalsgard, C. (2006). Social software: E-learning beyond learning management systems. *European Journal of Open, Distance and E-Learning*.

Devaney, L. (2013, October 3, 2012). Education chief wants textbooks to go digital, *eSchool News: Technology News for Today's K-12 Educator*. Retrieved on June 15, 2016 from http://www.eschoolnews.com/2012/10/03/education-chief-wants-textbooks-to-go-digital/

Digital Content Goes to School: Trends in K-12 Classroom E-learning. (2016). Retrieved on July 3, 2016 from http://www.ascd.org /digitalcontentreport

Drijvers, P., Tacoma, S., Besamusca, A., Doorman, M., & Boon, P. (2013). Digital resources inviting changes in mid-adopting teachers’ practices and orchestrations. *ZDM Mathematics Education, 45*(7), 987-1001. doi:10.1007/s11858-013-0535-1

Edson, A. J. (2016). A design experiment of a deeply digital instructional unit and its impact in a high school classroom. In M. Bates & Z. Usiskin (Eds.), *Digital Curricula in School Mathematics* (pp. 177-203). Charlotte, NC: Information Age Publishing.

Feldstein, M. (2016, June). Adaptive Learning Earns an Incomplete, *The Chronicle of Higher Education*. Retrieved on June 25 from <http://chronicle.com/article/adaptive-learning-earns->an/236758?cid=at&utm\_source=at&utm\_medium=en&elqTrackId=ce5ad2d0d9a24e9db4042c02343f4695&elq=f33375757b904cdfa4640e328c9787c7&elqaid=939

Fennell, S., Johnson, A., Milou, E., Murphy, S., Schielack, J., Sherman, H., Tate, W., & Wiggins, G. (2010). *digits*. New York. Pearson

Fletcher, G., Scaffhauser, D,, & Levin, D. (2012). *Out of Print: Reimagining the K-12 textbook in a digital age*: State Educational Technology Directors Association.

Garrison , D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education, 15*(1), 7-23. doi:10.1080/08923640109527071

Gueudet, G., Pepin, B., & Trouche, L. (2013). Textbooks design and digital resources. In *ICMI study 22-Task design in mathematics education* (pp. 327-338).

Hanson, K & Carlson, B. (2005). Effective Access: Teachers’ use of digital resources in STEM teaching. *Education Development Center, I*nc. Retrieved on April 15, 2005 from <http://www2.edc.org/GDI/publications_SR/EffectiveAccessReport.pdf>

Herold, B. (2016, March). What Mark Zuckerberg’s Pivot to Personalized Learning Means for the Ed-Tech Market, *Education Week*. Retrieved on July 13, 2016 from https://marketbrief.edweek.org/markettrends/whatmarkzuckerbergspivottopersonalizedlearningmeansfortheedtechmarket/

Heitin, L. (2016a, February). Where Are Teachers Getting Their Common-Core Instructional Materials, *Education Week*. Retrieved on April 20, 2016 from http://blogs.edweek.org/edweek/curriculum/2016/02/where\_are\_teachers\_getting\_their\_common\_core\_materials.html 1/

Heitin, L. (2016b, April). The Search for Common-Core Curricula: Where Are Teachers Finding Materials? *Education Week*. Retrieved on April 20, 2016 from <http://blogs.edweek.org/edweek/curriculum/2016/04/common_core_curricula_teacher_materials.html>

Herman, M. (2016, January). Data Dashboards a High Priority in National EdTech Plan, *Education Week*. Retrieved on January 25, 2016 from <http://www.edweek.org/ew/articles/2016/01/13/data->dashboards-a-high-priority-in-national.html

Kasten, S. E., & Sinclair, N. (2009). Using Dynamic Geometry Software in the Mathematics Classroom: A Study of Teachers' Choices and Rationales. *The International Journal for Technology in Mathematics Education, 16*(4), 133.

Kraidy, U. (2002). Digital media and education: Cognitive impact of information visualization. *Journal of Educational Media, 27*(3), 95-106.

Labaree, D. (1997). Private goods: The American struggle over educational goals. *American Educational Research Journal, 34*(1), 39-81.

LEAD Commission. (2012). Leaders discuss transition to digital textbooks. *Leading Education by Advancing Digital*. Retrieved on August 1, 2016 from <http://www.leadcommission.org/news/leaders-discuss-transition-digital-textbooks> .

Lew, H. (2016). Developing and implementing "smart" mathematics textbooks in Korea: Issues and challenges. In M. Bates & Z. Usiskin (Eds.), *Digital Curricula in School Mathematics* (pp. 35-51). Charlotte, NC: Information Age Publishing.

Means, B., Peters, V., & Zheng, Y. (2014) *Lessons from Five Years of Funding Digital Courseware: Postsecondary Success Portfolio Review.* Menlo Park, CA: SRI Education.

Meyer, A., & Rose, D. (2000). Universal design for individual differences. *Educational Leadership, 58*(3), 39-43.

Molnar, M. (2016, January). Flood of Open Education Resources Challenges Educators Districts seek curation tools for organization, *Education Week*. Retrieved on March 15, 2016 from http://www.edweek.org/ew/articles/2016/01/13/flood-of-open-education-resources-challenges-educators.html

Organisation for Economic Co-operation and Development. (2007). *Giving knowledge for free: The emergence of open educational resources*.

Ritella, G., & Hakkarainen, K. (2012). Instrumental genesis in technology-mediated learning: From double stimulation to expansive knowledge practices. *International Journal of Computer-Supported Collaborative Learning*, *7*(2), 239-258.

Saltman, K. (2016) Corporate schooling meets corporate media: Standards, testing, and technophilia, *Review of Education, Pedagogy, and Cultural Studies*, 38:2, 105-123, DOI: 10.1080/10714413.2016.1155953

Selwyn, Neil. (2007). Curriculum online? Exploring the political and commercial construction of the UK digital learning marketplace. *British Journal of Sociology of Education, 28*(2), 223-240.

Tuomi, I. (2013). Open Educational Resources and the Transformation of Education. *European Journal of Education, 48*(1), 58-78. doi:10.1111/ejed.12019

UNESCO (2012) *2012 Paris OER Declaration* (Paris, UNESCO). www.unesco.org/

U.S. Department of Education. (2016). *Future ready learning, reimagining the role of technology in education: 2016 National Education Technology Plan*. Washington, DC. Retrieved March 1, 2016 from http://tech.ed.gov.

Usdan, J., & Gottheimer, J. (2012). *FCC Chairman: Digital textbooks to all students in five years*. Retrieved February 1, 2016 from http://www.fcc.gov/blog/fcc-chairman-digital-textbooks-all-students-five-years

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Yarnell, L., Means, B., & Wetzel, T. (2016) *Lessons Learned from Early Implementations of Adaptive Courseware.* Menlo Park, CA: SRI Education.

Yerushalmy, M. (2016). Inquiry curriculum and e-textbooks: Technological changes that challenge the representation of mathematics pedagogy. In M. Bates & Z. Usiskin (Eds.), *Digital Curricula in School Mathematics* (pp. 87-106). Charlotte, NC: Information Age Publishing.

Yettick, H. (2016a, February). Why School Leaders Are Turning to Open Educational Resources, *EdWeek Market Brief*. Retrieved February 24, 2016 from <https://marketbrief.edweek.org/exclusive-data/open-educational-resources-school-districts-increase/>

Yettick, H. (2016b, April). What District and School Leaders Really Want From Personalized Learning, *EdWeek Market Brief*. Retrieved July 13, 2016 from

Yettick, H. (2016c, May). Remedial Resources, Core Academic Needs Driving K-12 Leaders’ Digital Content Demands, *EdWeek Market Brief*. Retrieved July 13, 2016 from <https://marketbrief.edweek.org/exclusive-data/remedial-resources-core-academic-needs-driving-k-12-leaders-digital-content-demands/>

Yettick, H and Reimer, A. (2016, March). Affordability is a Top Digital-Content Challenge for Educators, *EdWeek Market Brief*. Retrieved July 13, 2016 from https://marketbrief.edweek.org/exclusivedata/affordabilitytopdigitalcontentchallengeeducators/

Zhao, Y., Zhang, G., & Lai, C. (2010). Curriculum, digital resources and delivery. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International Encyclopedia of Education* (pp. 390-396). Oxford: United Kingdom: Elsevier Ltd.