ENACTMENT OF DIGITAL CURRICULA IN ELEMENTARY CLASSROOMS AND IMPACT ON MATHEMATICAL PRACTICES

Shannon O. S. Driskell
University of Dayton
sdriskell1@udayton.edu

Steve Rhine
Pacific University
steverhine@pacificu.edu

Ann Wheeler
Texas Woman's University
awheeler2@twu.edu

Rachel A. Harrington
Western Oregon University
harringtonr@wou.edu

Our consortium of four universities conducted case studies with five teachers in Grades 1 through 4 to explore how elementary teachers are implementing digital curricula, particularly whether they are developing the Mathematical Practices with digital curricula. Through observations with the Mathematics Classroom Observation Protocol for Practices (MCOP²), a survey, and interviews, we found evidence that there is a broad range of implementation strategies for digital curricula—from occasional use to daily use and from supplemental curricula to full curricula. This study indicates that best practices can be identified and developed for implementing digital curricula effectively in elementary mathematics classrooms. The research has implications for teacher educators and for professional development of inservice teachers teaching with digital curricula.

Keywords: Technology, Elementary School Education, Digital Curricula, Curricula Analysis

With the transformation to digital learning, many school districts are shifting toward one-to-one technology for all students. Due to such initiatives, school budgets for digital curricula are quickly rising: from $1.8 billion in 2013 to $4.8 billion in 2014 (Cauthen, 2017). From 2015 to 2016, digital curricula expenditures increased by 25% so that digital curricula cost "now exceeds all K12 spending by $3.5 Billion" (Kafitz, 2017, n.p). The promise is that "digital devices, software, and learning platforms offer a once-unimaginable array of options for tailoring education to each individual student's academic strengths and weaknesses, interests and motivations, personal preferences, and optimal pace of learning" (Herold, 2016, n.p.). Companies are "rolling out programs in America's public schools with relatively few checks and balances" (Singer, 2017, n.p.). EdSurge (www.edsurge.com) currently lists 175 digital core curricula for elementary mathematics. These curricula are rapidly spreading into elementary classrooms. For instance, Dreambox claims that over two million students are currently using their K–8 program in the United States (Singer, 2017). With pressure on schools to improve test scores and rise to expectations of the Common Core State Standards (CCSS; National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) or individual state standards, districts are seeking solutions for differentiated learning and data-driven instructional decision making. The shift to digital curricula to personal math instruction leads to questions about its support of student learning.

For our study, we examined how teachers implement digital curricula, particularly in regard to Mathematical Practices. We adopted the definition proposed by Pepin, Choppin, Ruthven, and Sinclair (2017) for "digital curriculum materials/resources/programmes" (DCR):

Otten, S., Candela, A. G., de Araujo, Z., Haines, C., & Munter, C. (2019). *Proceedings of the forty-first annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. St Louis, MO: University of Missouri.

> It is the attention to sequencing—of grade- or age-level learning topics, or of content associated with a particular course of study (e.g., algebra)—so as to cover (all or part of) a curriculum specification, which differentiates DCR from other types of digital instructional tools or educational software programmes (p. 657).

Further, Choppin & Borys (2017) note that "digital materials have potentially transformative features, such as enhanced interactivity, customization, and adaptive assessment" (p. 663). Accordingly, we adopted Pepin et al.'s definition and further clarify it to include only digital curricula that collect and save student data for teachers' use, as assessment is a powerful aspect of digital curricula that can impact teachers' instruction.

Related Literature

Researchers are just beginning to study the effectiveness of digital curricula and the results vary. The self-funded study conducted by the digital curriculum iXL in California found a strong positive correlation between iXL usage and state test scores (Empirical Education, 2013). A randomized control study with 4th-grade students and the Odyssey program found no significant increase in students' achievement when students used the program for one hour per week (Wijekumar, Hitchcock, Turner, Lei, & Peck, 2009). SRI International is studying learning behaviors in digital learning environments as well as the efficacy of the Reasoning Mind mathematics curriculum (SRI Education, 2018). These studies generally focus on the students' experience rather than what teachers do in the classroom.

In another study, Taylor (2013) reported that more than 29,000 classrooms in 216 countries were using Khan Academy (KA). Salman Khan, founder and executive director of KA, recommends using KA to personalize instruction, freeing up class time for engaging, high-yield activities like student discourse and meaningful collaborative projects (Khan, 2012). Khan added that, "ironically, the technology makes the classrooms more human for the teachers and students. It has also made the teachers that much more valuable" (Weltner, 2012). Contrary to Khan's recommendation, however, in a small study, Cargile and Harkness (2015) found that KA was not used to foster more active learning in the classroom; nor was instruction customized to students' progress and achievement levels. Based on the limited and conflicting research on how these programs are being implemented in schools, we have much to learn about choices teachers are making and the mathematics students are learning with digital curricula.

Theoretical Framework

Our theoretical framework consists of four factors that influence teachers' decision making with digital curricula. The first factor is teachers' self-efficacy about their mathematics and technology knowledge. "Academic self-efficacy, teacher self-efficacy, and computer self-efficacy are important predictors of the attitude toward computer-assisted learning" (Yeşilyurt, Ulaş, & Akan, 2016, p. 592). Many elementary teachers bring their own mathematics anxiety with them into the classroom (Bursal & Paznokas, 2006; Haciomeroglu, 2014; McAnallen, 2010; Swars, Daane, & Giesen, 2006). Teachers with confidence in their mathematics tend to better transform lower-cognitive-demand problems into higher-demand problems (Son & Kim, 2016). The teacher's attitude toward using technologies in the classroom is a major factor in how successful technology integration will be (Tabata & Johnsrud, 2008).

A second factor is teachers' perceptions of the balance between procedural fluency and conceptual understanding. "Procedural fluency is the ability to apply processes, techniques, and strategies accurately, efficiently, and flexibly; to transfer these methods to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or approach is more appropriate to apply than another. . . Procedural fluency builds on a foundation of conceptual understanding" (NCTM, 2014).

Teachers' perceptions of the Mathematical Practices' role in learning is a third factor. Confrey and Krupa (2010) contend, "For students to become proficient in mathematics, they must internalize the eight Mathematical Practices (MP) as the means to learn and understand the content standards. The practices sustain mathematics as the content evolves" (p. 10).

Teachers' perceptions of the affordances and constraints of digital curricula that lead them to enactment patterns is the fourth factor. Studies on the teacher's role in the implementation of new curriculum have examined teachers' curriculum strategy frameworks (Remillard, 1999; Sherin & Drake, 2009), their curriculum enactment patterns (Son & Kim, 2016), and aspects of factors related to teachers' decisions on tasks or problems that they enact during class (Son & Kim, 2015). The decisions teachers make about curriculum can potentially enhance or hinder students' understanding of mathematics (Nguyen & Kulm, 2005).

Methods

Participants and Setting

Participants included five elementary classroom teachers in mostly Title I schools located in three different states that are located in three different regions of the United States: midwest, south, and west. All five teachers were using digital curricula to support student learning of mathematics. This was a purposeful sample (Patton, 2002) since we wanted to analyze the enactment of digital curricula in elementary classrooms and its impact on teaching and learning.

Data Collection

We chose to conduct case studies of five teachers in order to get a deeper understanding of how they approach the use of digital curricula in their classrooms. For our case studies, we used a survey, observations, and interviews to triangulate the data (Patton, 1999), which allowed us to develop a comprehensive understanding of these teachers' enactments of digital curricula. We developed a teacher survey to gather data about teachers' demographics; beliefs about teaching mathematics, teaching with technology, and teaching mathematics with digital curricula; use of digital curricula assessment data; beliefs about how the MPs are supported with digital curricula; and developing students' MPs. To follow up on their responses to the survey, we observed teachers' instruction that included digital curricula. We used the validated Mathematics Classroom Observation Protocol for Practices (MCOP^2) (Gleason, Livers, & Zelkowski, 2015) and field notes during classroom observations. The MCOP^2 is designed to measure the degree to which a K–16 mathematics classroom is aligned with the various practice standards set out by the Council of Chief State School Officers, NCTM, and MAA. While there are different state standards, there is a commonality across states regarding MPs, which is captured by the MCOP^2. Following classroom observations, we used a semi-structured interview (Hitchock & Hughes, 1989) to learn more about teachers' beliefs about teaching and learning with digital curricula.

Results

On the teacher survey, all five teachers strongly agreed that: a) All students need to have a range of strategies and approaches from which to choose in solving problems; b) Mathematics learning should focus on developing understanding of concepts and procedures through problem solving, reasoning, and discourse; and c) The student's role is to actively make sense of mathematics tasks by using varied strategies and representations, justifying solutions, making connections to prior knowledge or familiar contexts and experiences, and considering the reasoning of others. All five teachers disagreed that: a) Students need only to learn and use standard computational algorithms; and b) The role of the student is to memorize information that is presented and then use it to solve routine problems on homework, quizzes, and tests. For the other two questions: a) two somewhat agreed and three disagreed that mathematics learning should focus on practicing procedures and memorizing basic number combinations, and one somewhat agreed and four disagreed that students can learn to apply mathematics only after they have mastered the basic skills.

All five teachers reported that they were confident in their use of technology in the classroom. However, their confidence differed in using digital curricula to teach mathematics: one was very confident, one confident, two somewhat confident, and one not confident. These teachers also varied in their responses to the effectiveness of digital curricula to learn mathematics and to develop factual recall, procedural fluency, conceptual understanding, and mathematical reasoning/problem solving (see Table 1)(no teachers disagreed).

Table 1: Teachers' Responses to the Effectiveness of Digital Curriculum

	Mathematics Learning	Factual Recall	Procedural Fluency	Conceptual Understanding	Reasoning/ Problem Solving
Strongly Agree	1	2	1		
Agree	2	2	3	4	2
Somewhat Agree	2	1	1	1	3

Further survey results indicate that all five teachers use digital curricula for skill and practice, four use it to differentiate instruction, and four use it for acceleration of content; only one teacher uses it to support critical thinking. During their planning and instruction, four teachers often and one teacher sometimes intentionally spends time developing either the MPs or their state's own process/practice standards. See Table 2 for a summary of the varied ways the teachers report using digital curricula to assist students in developing the MPs.

Table 2: Teachers' Reported Use of Digital Curricula to Develop the MPs

	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8
Extremely Well						1	1	1
Well	3	3	2	4	4	4	3	4
Not So Well	2	2	2	1	1		1	
Not At All			1					

To capture further evidence of teachers' enactment of digital curricula and its impact on MPs, we share case studies of each teacher.

Case Study of Allison

Allison is a 3rd-grade teacher with an emergency credential in her second year of teaching. She is a confident early-career teacher who loves teaching mathematics and is passionate about her students understanding concepts and developing procedural fluency. She has never taught any other way than with digital curricula. Her district requires her to use Go Math! daily for primary instruction and Reflex Math for practicing procedural skills. Each Go Math! lesson begins with whole-group video instruction on a particular math concept.

Allison is keenly aware of the importance of developing the MPs with her students. She is not satisfied with simply pressing "play" for the Go Math! videos and having the computer "teach" her students. Instead, she designs preliminary activities to get her students thinking about the concepts prior to watching the video. When students watch the video, Allison stops it at key moments and poses questions to her students. She finishes the lesson with an additional activity designed to enhance students' conceptual understanding. For example, when teaching a lesson on fractions, Allison had the students first think about a "fair share." While analyzing squares divided into fourths two different ways, Allison asked the students to think about whether all the pieces in the squares were fourths and to be prepared to justify their reasoning. After individual time, pairs met to discuss their thinking. She then chose certain students to explain their partner's thinking and how it was the same or different from than their own (example of MP2). She purposely chose those students to provide a range of perspectives.

After this class discussion, Allison started the Go Math! video lesson. She frequently—about every 30 seconds—stopped the video to pose purposeful questions: What do you think he will do next? (MP1). What do you think of the strategy he uses? Is there another strategy? (MP2). Can you draw a picture of what he is talking about? What would be a word problem for this number sentence? (MP4). Can you write that number sentence a different way and get the same answer? (MP4). After the Go Math! lesson, she gave each student a square from a chocolate candy bar, asked them to break the square into two or more pieces to form a new shape, and then asked, "Do you still have a fair share even though it is a different shape?" (MP4).

As Allison considered how to make teaching with digital curricula more effective for her students, she wondered: What things can I do before that will enhance the digital curricula? Where should I stop the video and discuss/predict? How can I make it more meaningful for them? She was enthusiastic about the data available on individuals' progress and eager to make use of that data to inform her teaching choices and differentiate instruction. Allison resisted when administrators insisted on fidelity of the program's implementation, arguing that she was acting in the best interest of her students' understanding. She was very concerned about other teachers in her building who were not as confident in teaching elementary mathematics and would simply press play and let the program "teach" their students. Even as an early-career teacher, she was considering ways to help enhance other teachers' work with digital curricula.

Case Study of Elise

Elise is a 4^{th}-grade teacher who has been teaching for 14 years. She is certified for Grades 4 through 9. She truly enjoys teaching mathematics, and teaches it for about 75 minutes each day. The school district adopted Eureka Math as the paper curriculum and Zearn as the digital curriculum. Although it's not required, the administration strongly encourages her to use Zearn. Each week, Elise's students use it for about 45 minutes during math class, an additional 20 minutes outside of math class, and about 45 minutes at home. The content the students explore in

Zearn typically aligns with the daily objectives. She chooses to use Zearn for acceleration, differentiation of instruction, remediation, and skill and practice.

Students typically used Zearn for 20 minutes when Elise organized different stations. All Zearn lessons began with *Number Gym* or an individually adaptive fluency experience for math skill practice. Next, students completed a fluency *Blast* that was aligned with the lesson and was the same for all students. Students then completed a guided practice and solved real-world problems that used the concrete, to pictorial, to abstract approach (MP1). Afterward, students transferred their digital learning to pencil and paper to draw representations of their thinking process (MP4). Finally, students began independent practice in the *Tower of Power*. Elise did not interact with the students while they worked on Zearn. Therefore, Elise did not personally engage the students working on Zearn in developing MPs.

During the interview, Elise expressed, "I would rather me doing instruction with them, and me working with them than having a computer program work with them." She did not feel that using digital curriculum changed her instruction: "I am still very much concrete, pictorial, abstract." She believed that it was "hard to monitor when they are on a computer because you don't even know if they are on the program half the time." As for teaching the MPs, she felt, "it is hard with Zearn. I see it like a remediation of what we have done in class." She wanted "to see their work" so that she could ask the students to analyze their work and "learn from their mistakes and have a discussion about it." She informed me that she knew students need to do math on the computer because they take the state test on the computer. She believed that there is a time and place for digital curriculum, but she did not want to be required to use it because it limits her teaching. "It's almost like you're micromanaging instead of trusting the individual teachers to make best choice for best practice for the students in their classroom." Elise did clarify that her confidence in teaching mathematics allowed her to see herself as a math teacher, but most elementary teachers "don't see themselves as a math teacher . . . they don't know the why behind the how." Those teachers, Elise felt, may rely on digital curricula more than she would, because she won't let the computer take over her teaching.

Case Study of Lindsay

Lindsay is a 1st-grade teacher who is in her third year of teaching. Her school district adopted Pearson's enVisionmath2.0(C) as the paper curriculum and Istation as the computer adaptive web-based platform, utilized for about 60 minutes during Specials time in a computer lab once a week. Istation is used during regular class time for an additional 20 minutes per week. Even though Istation covers 1st-grade content, it is not meant to align with the daily mathematics objectives. Lindsay utilizes its content for acceleration, skill practice, and Specials time.

Lindsay's two observations during class and during Specials time were noticeably different. Lindsay's typical 45 minutes of instruction began with a brief introduction to balancing equations. The class then proceeded to work in groups of 2–4 students with various mathematics manipulatives, such as Unifix cubes, two-color counters, dice, blocks, and balances, as well as dry-erase markers and whiteboards (MP4). Students were tasked with writing multiple equations that would balance (e.g., $4 + 1 = 5 + 0$) and explaining their logic to their group (MP1, MP3, and MP7). Lindsay constantly walked around to help struggling students and to encourage students to do their best. At the end of the lesson, the students came back together on the carpet to review what they had learned, with some students sharing their equations with the whole class (MP6).

As opposed to this interactive whole-class discussion and activity lesson, the Istation lesson involved students individually working on their mathematics problems. Students wore headphones and were encouraged to be quiet and work hard by themselves. If students struggled with the content, Lindsay answered their questions. Individual Istation problems varied, based on student ability. Many of the problems included interactive components, with students often singing or dragging virtual manipulatives around the screen. If students had difficulty with a concept, they were given multiple problems to help them. If they passed, they would move on in the content; if they struggled, the program would not move on to new content. Throughout this lesson, Lindsay did not engage students personally in developing MPs.

During her interview, Lindsay expressed her love for teaching mathematics face-to-face and the importance of student interactions. Lindsay felt that digital curricula were helpful as practice for procedural and conceptual fluency. She also felt that the more advanced students and those who struggled preferred digital curricula. The advanced students like to work at their own pace, and those who struggle felt the computer was sort of a safe space for them because they could make mistakes and no one would see them struggle.

Case Study of Sarah

Sarah is a 5th-grade teacher with nine years of teaching experience. She is certified for kindergarten through 5th grade and recently earned the Elementary Mathematics Instructional Leader Specialization. She truly enjoys teaching mathematics and is considered a leader in her district and school. The school district uses Eureka in 3rd-5th. The teachers also have access to IXL, which was chosen by district administration. Teachers were not given specific professional development on how to use it, and it is their discretion on how to implement it. Sarah's students typically spend one day a week on IXL, and she chooses a standard from that week's instruction for them to explore. In the interview, she shared that she sees IXL as a time for students to practice at their own pace. She also sees it as a time for students to have a "break" from Eureka and for her to have a "break" from planning. She does not use the data generated by IXL for instructional purposes, and she does not share results of student work with parents or guardians.

Sarah was observed twice: once while teaching a typical lesson and once on an IXL day. In the typical lesson, she introduced the concept of division. She had students out of their seats, grouping themselves into different animal herds. She asked the students to make observations about group size, number of groups, and remainder size (MP1, MP2, and MP4). On the IXL day, students worked quietly on tablets as she moved around the room answering individual questions. Sarah focused most of her time on a few students who needed extra support. In contrast to the first observation, Sarah was developing only MP1 with her students.

Case Study of Shelby

Shelby is a 3rd-grade teacher who is in her sixth year of teaching. She taught 8th grade for one year at a different school; since then, she's taught 3rd grade at her current school. Shelby's school district adopted Pearson's enVisionmath2.0(C) as the paper curriculum and Istation as the digital curriculum, which the students utilize for about 40 minutes during Specials time in a computer lab once a week and 1.5 hours per week during class time. The main digital curriculum for 3rd grade is Istation, but the computer lab teacher is also piloting Prodigy for potential future use instead of Istation. Students may access Istation at home, but are not required to do so. The Istation lessons are not meant to align with the daily mathematics objectives but do cover grade-level content. Shelby utilizes its content for acceleration, homework, differentiation, remediation, skill practice, and Specials time. Students independently work at their own pace with the content.

Shelby's two observations were clearly different. Shelby's 60-minute in-class observation involved students working on a warm-up as a review of previously learned mathematics concepts. Students then went to the carpet. Shelby gave certain students construction paper and students worked through scenarios as a class involving fractional relationships, such as $\frac{1}{4}$ and $\frac{3}{5}$

(MP3 and MP4). Students then went back to their seats and listened to the ebook *Give Me Half* by Stuart Murphy. Shelby asked students to write certain answers to fraction questions, and also reinforced their learning with playdough-based fraction work (MP1 and MP4). Lastly, Shelby had her class complete a fraction pizza worksheet (MP7). Shelby actively walked around the class, asking engaging mathematics questions and helping struggling students (MP6).

During the Istation lesson, students were quietly working through problems on their own. If stuck, some students used whiteboards or paper and pencil to figure out problems. Some students had difficulty with the vocabulary, in which case Shelby reassured them to try their best. Like Lindsay's students, Shelby's students often had interactive mathematics manipulatives on their screens that they could drag and drop to figure out such concepts as multiplication and rounding. Throughout this lesson, Shelby did not engage students personally in developing MPs.

During her interview, Shelby expressed her desire for more control over the content students were learning in the digital curricula, and she wanted the ability to choose the weekly math standards. Although there were downsides to Istation, Shelby felt the engagement aspect of digital curricula was good for students. She also liked that the program identified students' strengths and weaknesses, and that it provided practice. In addition, Shelby felt that unmotivated students or students who have "tuned out" the teacher learn best from digital curricula.

Discussion and Conclusion

Although there was some consistency in teachers' beliefs about teaching mathematics and in their confidence in using technology, there were some inconsistencies among their confidence in teaching mathematics with digital curricula, their beliefs about the effectiveness of digital curricula, and their use of digital curricula to assist students in developing the MPs. Several other differences were evident in how teachers enacted the digital curricula—independent work, large-group instruction, and stations. Two teachers enacted digital curricula during Specials, while three teachers enacted it during math class.

The perceived benefits of digital curricula also varied. One teacher noted the personalized instruction aspect and thought that the advanced students enjoyed being able to work ahead, while the struggling students felt safe making mistakes without being noticed. Identifying students' strengths and weaknesses, instant feedback, practice time, and students' increased success on standardized assessments were also perceived benefits. The change from interacting with peers to interacting with the computer was a concern of one teacher. Not being able to see students' work so that she could analyze their mistakes with them was a reason one teacher would rather use paper and pencil versus a computer for instruction. Several teachers expressed concern that they lacked control over what content students learned or what websites they explored, or even felt a loss of their own teaching identity.

Navigating the shift to digital learning presents several obstacles for teachers, and teachers need ways to deal with such obstacles. There is a separate knowledge base for teaching with paper and pencil than for teaching with digital curricula, and addressing this knowledge base needs to be one focus of preservice teachers' education programs and inservice teachers' professional development programs. With the advancements of innovative technologies in this digital age, digital curriculum is here to stay—at least for the near future. Teacher education and professional development programs must support teachers through the shift to digital learning. The State Educational Technology Directors Association, in *Navigating the Digital Shift 2018: Broadening Student Learning Opportunities,* recommends that "States must provide leadership as educational opportunities switch to the use of digital instructional materials to support student learning and successes" (p. 2). We echo this call and further recommend that teacher education programs address preparing preservice teachers to navigate this shift.

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