Exploring Emerging Technologies in Digital Media Content for Middle School Math Education

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Introduction

Overview of Emerging Digital Technologies

The transition from print content to digital content allows opportunities for enormous changes in how middle school mathematics is being taught in the United States. Schools are facing not only the challenge of teaching mathematics in the Digital Age but also new challenges with the Common Core State Standards for Mathematics (CCSSM). Students are striving to grasp mathematics with these new standards and teachers are still cultivating new approaches to teaching mathematics with new digital technologies.

These transitions have also repurposed enormous pressure on the publishing industry, which traditionally provides content and curriculum in the form of textbooks. With new digital media that can easily be disseminated, there are new demands to create content that both aligns with CCSSM and fits the demands of a twenty-first century math classroom. The shift to digital content, when combined with CCSSM, has created textbooks which are not only physically outdated as a classroom technology but also obsolete in terms of content. The goal of this paper, then, is to develop an analysis of the migration from print media to digital media and the implications for effectiveness of learning technologies in the grades six to eight math classroom.

Beyond *what* the twenty-first century math textbook will look like, there is also a significant question of *how* middle school students will learn mathematics through emerging

digital educational technologies. For a long time, textbooks have driven specific mathematics curriculum and served as the primary tool for instructional materials (see Merseth, 1994), but now teachers have the flexibility to individualize their instruction to specific needs.

Without a print textbook driving a mathematics curriculum, teachers have the ability to access content through e-textbooks, digital learning platforms, online learning communities, and even write content themselves. Students can also access various forms of digital media such as instructional videos, problem generators, mobile applications, and computer assisted instruction. Mickey & Meaney (2014) noted that there is no print book in these educational programs, and educational companies are centralizing their products towards classroom specific needs with digital platforms (p. 62).

In spite of these new digital technologies emerging, the middle school mathematics curriculum continues to feel handed down and prescribed to teachers from districts adopting and prescribing educational products which are produced by publishing companies. According to Banilower (2013), 83 percent of middle school mathematics classrooms use textbooks, whether digital or print (p. 91), and as Herold (2015) indicates, the push for mathematics content is being standardized by CCSSM and then produced by publishing houses (p. 2). Thus the middle school math content produced by publishing companies remains an important part of mathematics instruction, and as market reports from Richards & Stebbins (2014) indicate, schools continue to adopt content produced by publishing houses (p. 1). Given the large amounts of money schools spend on content and the high degree to which teachers use these materials, it is thus important to include the publishing industry as part of the discussion in how students will learn mathematics with emerging digital technologies.

Benefits and Potential of Digital Technologies

With these topics surrounding us in math education, my analysis which follows focuses on how education companies have responded to the shift from print media to digital media and how well companies' digital content follows a particular CCSSM strand—mathematical standards for grades six to eight. I chose to look at grades six to eight mathematical instruction for several reasons. First, as a seventh grade math student, I remember dreading mathematics class because it was taught through rote memorization and timed tests with little to no room to explore abstract thinking. I want middle school students to have a better experience. Second, in my background as a middle school mathematics teacher, I have encountered many perceptions from parents, colleagues, and friends on how to teach middle school mathematics, and as my literature review will show, we now have CCSSM to provide adequate guidance. Third, although we do not know the causal link, Secretary of Education Arne Duncan stated at an NCTM national conference that the best predictor of a student's success in a 4-year college is how well a student succeeds in algebra[1], meaning middle school math topics are critical for college preparation (personal communication, April 15, 2011). In my research, I have found many discussions of educational problems in grade six to eight mathematics instruction (see Boaler, 2014, Lockhart, 2002, Merseth, 1994), and if twenty years of the same problem in education repeating itself is no indication, I would like to ensure that as a math educator, I help get it right with these new changes in standards and technology.

In T-561, we talked about how the primary role of a school is to foster transfer of learning to prepare students for becoming productive adults. To that end, creating mathematical representations using digital tools could foster the vehicle for teaching and learning real mathematical practices outlined by CCSSM. In fact, NCTM has stated, "It is **essential** that teachers and students have regular access to technologies that **support and advance** mathematical sense making, reasoning, problem solving, and communication. [...] When teachers

[1] Duncan was likely citing Jonas et. al. (2012).

use technology strategically, they can provide **greater access** to **mathematics** for **all** students." [emphasis mine] (2015). In addition, leaders in math education propose teaching mathematics through strategies, formative evaluation, and making connections between ideas (see Boaler, 2014, Meyer, 2015, and Yerushalmy, 2006). From the past decade, the literature has argued that adaptive mathematics technologies have a small effect size and traditionally focus on "drill and kill" (see Clark, Chueng, & Slavin, 2013). In addition, the hope is that with CCSSM, we witness a movement Dede (2009) proposes in education to shifting math instruction from knowledge, skills, and memorization to the ability to retrieve information, higher-level thinking, problem-solving, and decision-making (p. 34). Because digital content can be disseminated by and for math educators, this allows opportunities for scalability design (see Dede, 2014), and potential for teachers to collaborate, share, and adjust content quickly for learning needs.

Analysis of Whether Shift is Transformative or Conventional

To find out whether the shift from print media to digital media in the mathematics classroom is a transformative technology, I followed the analysis proposed in Christensen, Horn, Caldera, & Soares (2011). In their report, the authors discuss that if one calculates the ratio of the market share from the new technology to the market share of the old technology and plots it on a logarithmic vertical axis, this technology will follow a linear curve (pp. 29-30). I took Simba market share reports from the past decade for the PreK to 12 publishing industry and found that the technologies, when plotted, share a mostly linear curve. Figure 1 shows the scatterplot of the two variables, and the linear regression equation is $ratio = .02*(year)-33.17$, R-squared = .75. In addition, Figure 2 shows the overall trends in the global e-book revenue from 2009 to 2016.

What I found interesting about this exercise is mostly two things. The first is that 2015 is an important year. If we could describe this technology as transformative, the shift is happening right about now with the market share ratio currently at 48 percent. As my qualitative analysis will indicate, publishers are gearing up for this. The second is that educational companies seem to be responding to the demands for types of content driven by national standards. For example, the outlier in 2005 likely results from the No Child Left Behind Act. From that year, Meaney, Mickey, & O'Brien (2004) write, "as schools seek more broad-based solutions in the No Child Left Behind era, publishers have enhanced their products, creating courseware with instructional management, assessment, individualized learning paths and professional development" (p. 1). So, the idea of publishers responding to educational product needs shows that the people who buy textbooks or influence those that do serve as publishers' incentive. As a result, the publishing industry is exploring transformative technologies and new platforms that are changing the PreK to 12 publishing industry.

The third thing to acknowledge is that in spite of all the recent literature and articles highlighting the shift from print to digital media, progress remains very slow in middle school math classrooms, which is why I claim this technology is transformative, not disruptive (see Christensen, Horn, Caldera, & Soares, 2011). In Figure 1, notice the positive slope indicated is on the order of hundredths. Although headlines claim that districts and schools are currently pressuring publishers to overhaul the way that they deliver content, after my experiences as a teacher and speaking to experts in the publishing industry, I remain skeptical to the rapid pace that this technology is shifting.

Overview For the Remainder of the Paper

The objective of this paper is to provide a research synthesis that analyzes the shift from print media to digital media in the middle school mathematics classroom, and publishers' responses to it. The goal of the analysis is to assess the function and value of digital platforms given their affordances for educational benefits. Thus, this analysis will be guided by a few research questions, including:

- How do new digital platforms transform math publishing?
- How do these new platforms affect content development?
- What new technologies are publishers currently using to create content?
- What are the affordances of new technology in terms of teaching math?

I will explore some theoretical and empirical framework for this technology, and especially will look at the effectiveness of promoting deep learning in mathematics through technologies as outlined by CCSSM. As of May, 2015, 43 states, the District of Columbia, four territories, and the Department of Defense Education Activity have adopted CCSSM (Common Core State Standards, 2015), which is why we will especially look at the technologies through this framework.

Methods

For the purpose of this report, I define digital media broadly as technologies which are digital platforms, education software, services, and products which are used in grade six through eight mathematics instruction in the United States. These digital products and services may be used inside and outside the classroom (see Table 2). I do not include hardware such as computers, tablets, smartphones, and calculators.

I will analyze the effects of digital media through current literature, my personal experiences, what researchers and publishers are saying, and qualitative data collected. In order to gather qualitative data, I corresponded with a total of 13 professionals, all from different publishing houses, who are working on projects related to middle school mathematics instruction. These projects emerged from for-profit and not-for-profit companies. Four separate participants, all from the for-profit sector, responded to the initial invitation to participate. One participant interviewed was a product developer, one was a content developer, one was a senior level editor, and the fourth was a CEO. The interview protocol is included in Appendix A.[2] I sorted the data based on industry concerns, industry topics, and participant attitude (see Table 1). By triangulating between the literature, the products, my personal experiences, and qualitative data, I hope to provide a rich analysis of how digital media has impacted the middle school classroom, and how middle school children and teachers are using it to learn mathematics.

Timeline

The timeline of this research follows:

Date:	**Action:**
January & February, 2015	Research for literature review
February & March, 2015	Obtain IRB approval
March, 2015	Collect data
April, 2015	Data analysis and preliminary interpretations
May, 2015	Final Report

Ethical Considerations

To protect confidentiality, identifiable information was not collected during the data collection in my report. I did not collect video recordings or tapes during the interview stages.

[2] *Note:* Following IRB approval, the raw data is shared with C. Dede (personal communication, April 14, 2015). Visit Google Drive for more information.

Participants signed an informed consent form prior to participating in this qualitative study (see Appendix B). The written consent form included information about the study, the duration for which participants would participate, potential risks and discomforts, my contact information, and a statement that the data collected was confidential and only to be shared with researchers involved. I made it clear that their comments and opinions were not to be used to evaluate them but only to be used in this report.

Overview of Literature

Description of the Theory of Learning Trajectories

Perhaps the most compelling theory of learning and teaching that the shift from print to digital platforms could exemplify is learning trajectories, which is a theory of learning developed by J. Confrey (personal communication, April 18, 2015). The idea is that students learn mathematics actively through iteration, and that there are multiple pathways through which a student can scaffold from prior knowledge to abstract reasoning (see Clements, & Sarama, 2014). As J. Confrey notes, using a learning map that follows CCSSM standards[3] tied with learning analytics, this creates a formation for how students learn mathematics on digital platforms (personal communication, April 18, 2015). J. Confrey indicates that a robust learning trajectory supports students' learning interpersonally on digital platforms. For example, interactive graphing calculators could be used in the middle school math classroom both as iterative and interpersonal math technology that can help students approach supportive instruction with a growth mindset (see Dweck, 2000). Students can then reach the next step in approaching learning goals as outlined by CCSSM (personal communication, April 15, 2015). As Clements indicates, scaling up learning trajectories is a possibility (see Clements, D.H. &

[3] Visit http://sudds.ced.ncsu.edu/ for more information about The Learning Map Project.

Sarama, J, 2014), and according to J. Confrey, Pearson is currently working with researchers to develop digital platforms that address this need (personal communication, April 18, 2015).

Discussion of Research Findings About Digital Technologies So Far

There is sizable debate in the literature regarding the benefits of digital technologies and the mathematics classroom. Chueng & Slavin (2013) argue that the overall effect size of these digital technologies in the K through 12 math classrooms is +0.16 (p. 96), which is modest. Computer assisted instruction (CAI) technologies had the highest effect size in the report, +.19 (p. 101). If these modest effect sizes are not convincing, Clark (1983) argued strongly that media will never influence learning due to educator tendencies to look for positive influences in the literature instead of negative influences (p. 28). Recently, Meyer (2015) analyzed 83 tasks across two years of mathematics textbooks which are claiming to show “mathematical modeling” set by CCSSM. In 76 percent of tasks analyzed, the textbook either gave models in text or tasks referred students back to sample problems. Of the textbooks analyzed, 20 of 83 withheld the mathematical modelling altogether. This meant that students could view mathematics as a set of formulas to memorize, not models to create. According to Star & Rittle-Johnson (2011) mathematical modelling in equation-writing are important methods for learning equation-solving (p. 574). In other words, the literature suggests that approaches to teaching mathematics shared by NCTM is not a new idea; instead CCSSM merely suggests calls to action for movement towards active classroom time spent doing mathematics. The question, however, is how classrooms are responding to these standards.

Comparison of Findings to Claims Made by Publishers

Beyond the different platforms which currently exist, there is some disjoint in the literature produced by advocates of digital math platforms. Publishers tend to exaggerate their claims on their products for educational effect; indeed J. Confrey noted that most publishing houses do not conduct adequate research on the impact of their products (personal communication, April 18, 2015). In response to these overstatements, a new organization, EdReports.org, has emerged for the purpose of checking how content produced by publishers stand up to CCSSM. So far, EdReports.org reports that their reviews cover over 60 mathematics platforms for grades K through 8.[4] On the website, I searched for reviews that cover middle school mathematics, which yielded 11 results. Of those reports, one platform met CCSSM—*Eureka Math,* published by Great Minds.

Analysis of What Is Known and What Remains To Be Discovered

We know that the shift from print to digital platforms is a transformational technology that is not going away. Although we cannot say with certainty how rapidly this shift will occur, the question is what learning opportunities this shift will leverage for mathematics instruction. In the past, new education technologies such as handheld calculators in the classroom have created tension between computational abilities and conceptual understanding for learning mathematics (see Ruthven, 1996). This tension is becoming more relevant with calculators now built in smartphones; indeed nearly 28 percent of middle school students carry smartphones to schools (Grunwald, 2013). There is also speculation for how mobile apps could afford learning opportunities for mathematics teaching and learning. There is currently some discussion in education regarding digital technologies and apps that are "gamified" learning experiences (see Fishman & Dede, 2015, Osterweil, 2011, Huizanga, 1950). The important thing to consider; however, is how these new technologies can afford transfer of learning for teaching and learning

[4] See http://www.edreports.org/methodology/index.html, 3rd. paragraph

deeper understanding in mathematics which follow CCSSM.

Teaching Math With Digital Media

A Personal Experience With Classroom Use

My experiences using digital technologies as a middle school mathematics teacher at a small independent school for 60 gifted students could be described as mixed. Our classroom was equipped with 21 TI-83 graphing calculators with an average class size of 15 students. Students were not allowed to bring personal digital devices to school or use them during the school day. Our middle school owned an iPad cart shared between five classrooms, plus our middle school shared 25 Mac laptops which could be reserved. Whenever we used digital devices, students extensively used free digital tools published online, such as calculators, search engines, programming tools, and Google Drive. For digital usage, we encountered barriers to online collaboration for students under 13 years of age due to COPPA laws.

My classroom had one desktop, an LCD projector, and as a teacher, I was issued a single iPad for classroom use. We primarily used the iPad for the Keynote or Desmos apps tied with the LCD projector, and often this technology was used for showing media using Dan Meyer's Three Act Math Tasks.[5] During class instruction, students would share ideas in small group discussion and would use personal-sized whiteboards to share ideas and actively think about mathematics. Primarily though, students were issued a print math textbook from the *Everyday Mathematics* series published by McGraw-Hill, and we used the textbook for both content and curriculum. Most content I followed was driven by a textbook already set in place, and changes in digital technologies each year was driven by new standards set forth by CCSSM, school evaluations, professional development, school funding, and individual teacher goals. When I reflect on my

[5] Visit threeacts.mrmeyer.com for more information.

personal experience, what I think about is how quality mathematics instruction comes not from the new technologies, but from integrating it within the curriculum and individual classroom needs.

Producing Math Products With Digital Content

Qualitative Analysis Findings[6]

As I reflected on the bigger picture in my experiences as a teacher and also a researcher, I revisited the qualitative data I collected to remind myself of the original analysis questions I set forth to analyze at the beginning of the semester. I designed the interview research instrument[7] around the following two questions:

i. What does a twenty-first century classroom look like for grades six through eight mathematics instruction?

ii. What are publishers' responses to these classroom needs?

The following table organizes the claims based on the driving question each addresses:

Question	Claims that address each question
What does a twenty-first century math classroom look like?	1. A twenty-first century math classroom emphasizes creative problem-solving, mathematical modelling, opportunities for collaboration, and mathematical fluency as outlined by CCSSM. 2. There is no typical twenty-first century math classroom due to scalability design in education. 3. Educational product consumers are becoming more selective and outspoken about their classroom individual needs than in the past.

[6] I base this qualitative analysis from suggestions by C. Reich in T-523: Formative Evaluation for Educational Product Development (personal communication, May 2015).
[7] See Appendix A for the instrument.

What are publishers' responses to these twenty-first century needs?	4. Survey participants envision a connected middle school math classroom with immersive digital experiences. 5. Survey participants base their products around market research and communication with customers. 6. Survey participants focus on school and student needs and hold themselves accountable for these needs. 7. Survey participants are producing different materials that provide more open-ended assessments for learning due to CCSSM. 8. Survey participants' companies at which they are employed are producing a blend of educational technology products and print products due to not all teachers adopting digital platforms. 9. Survey participants are working towards adaptive content that provides constant feedback. 10. Survey participants' comments acknowledge that the educational companies' products examined are currently not standing up to NCTM CCSSM strands for grades six through eight math instruction. 11. Survey participants are anticipating Common Core digital assessments, but otherwise seem unmoved by CCSSM for content development.

The 11 claims, with analysis from the data collected, follows in this section.

Claims and Supporting Analysis

Claim #1: A twenty-first century math classroom emphasizes creative problem-solving, mathematical modelling, opportunities for collaboration, and mathematical fluency as outlined by CCSSM.

Survey participants are acknowledging the transition period with CCSSM standards and the shift from print to digital technologies. Among the 60 comments coded in the data, 14 had comments relating to CCSSM standards. Within these comments, participants envision collaboration through digital platforms, mathematical modeling, and mathematical fluency for middle school students. One participant noted, "Our latest iteration involves standards for math practice is teaching students how to think like mathematicians in very different ways, not drill-and-kill math activity." A second participant noted that in five to 10 years, the publishing industry will experience a "disruptive time" with the print to digital shift. The products that participants describe include interactive platforms, open-ended activities, digital experiences, differentiated learning, problem-based learning, and open-ended math questions.

Claim #2: There is no typical twenty-first century math classroom due to scalability design in education.

Participants noted that their customers tend to come from a broad range of backgrounds, and their product development process reflects that. As will be shown in Claim #7, the types of products emerging from educational companies include print books, videos, digital learning platforms, PDFs, and mobile apps. From the data collected, we can conclude that schools in this century are consuming different products with different mediums.

Claim #3: Educational product consumers are becoming more selective and outspoken about their classroom individual needs than in the past.

Survey participants noted that one major change they have found in the past five years is that their customers are requesting particular products and are providing more feedback on new platforms. One participant noted that because the market is fragmenting with new digital technologies, customers are approaching publishers with individualized classroom needs and looking for specific platforms that address their teaching needs. The following dialogue from a second participant says,

Interviewer: What changes, if any, have you seen while you worked here?

Respondent: The biggest change I have witnessed is sophistication of customers. The way teachers talk about what they need has shifted. Customers are smarter

> about what they want. We are getting at the root of what other things are. The need for our products are going to increase as more as time goes on because teachers want more access to different types of assessments. I have witnessed much more complex needs than in the past. We are using content and manipulating it for schools. It's an interesting shift.

According to a third participant, because customers are now approaching companies with individualized needs, a number of small players in the publishing industry are emerging, with differentiated products that are learner-centered.

Claim #4: Survey participants envision a connected middle school math classroom with immersive digital experiences.

Although not all of the products that participants described are on the market yet, participants noted that connected classrooms are an important part of the educational publishing industry. When asked about future trends, participants spoke quite a bit to using the Internet to connect students with like-minded individuals, teachers, their company, or helping a child fit the necessary learning needs. When asked about current trends, participants noted that schools are slow to shift, but students are not. Of the six comments sorted relating to future trends, five of the comments related to gauging student progress and student success through digital experiences, so that students may use these technologies to get feedback quickly.

Claim #5: Survey participants base their products around market research and communication with customers.

When asked about their product development process, participants noted that they tend to release new products at a smaller scale first, and then work to distribute their products at a larger scale. One participant made an analogy that the industry is like “Amazon”—the customer may dream of a product, and "it will show up at your door." Another participant described the online curriculum development process for digital classes as follows:

Interviewer: Could you talk to me about one project that comes to mind that is related to a grade six to eight math classroom?

Respondent: [...] We like to see how the materials are seen over time. [We] call the classes "scripts," [and we] may use parts of the scripts as is or use as suggestions [in our digital classes]. [The] feedback comes to the mothership and us, [and] we use that to alter the classes for next time [...] A lot of our materials can get delivered and then get deleted or revised [...] We can look at the students longitudinally, [for example, at] "week 7 they fall off." This is something that good teachers can do individually but not institutionally.

Here is how a third participant noted the product development process:

Interviewer: Could you tell me about how the organization creates or maintains a new technology for mathematics education?

Respondent: We create our new product by reaching out to customers [to find out] what they want. We then conduct market research, go to classrooms, and ask what they are doing now and what they are lacking. This allows customer feedback and customers to be part of our process in data analytics. We talk to teachers in particular about what they want. We talk about what they think they want, by asking, "Is this what you want?"

This claim shows an interesting shift because teachers are now becoming advocates for their own classrooms. This also raises an interesting question for how schools may have requested products differently for print math textbooks in the past.

Claim #6: Survey participants focus on school and student needs and hold themselves accountable for these needs.

In the study, I coded comment attitudes as positive, negative, or neutral to find out how participants felt about the product development process. Six of the 60 comments coded were positive, six were negative, and 48 were neutral. Among the negative comments coded, the comments related to hoping to develop more rigorous materials that met CCSSM standards, questioning the educational effectiveness of their own products with hopes for improvement, and identifying problems in seeing what does and does not work. Among the positive comments coded, the comments related to the excitement of developing new products to meet new industry needs, creating content that works for students and teachers, and opportunities for revision after pilot testing a new product with educators. One participant's study summarizes the accountability feelings from the set of comments collected:

> "I think [that] things have changed some, but [we] have a long way to go. The hard thing is that it is so wildly different from student to student. [...] I can speak to what we do for our kids, and that is to remove the ceiling."

Overall, participants who were surveyed seemed concerned about their products' uses and expressed this in various comments. One participant noted:

"From a product developer standpoint, I feel that publishers and people in the industry who purchase things don’t spend as much time with kids as much as they should. I wish more time was spent seeing what kids like and what works. Research has been done about what works and what does not. Most products are more of a marketing ploy. The question of what works for kids and how to make a better product [...] focus[es] on research on industry. This doesn’t always leads to products but considers what kids like instead of what sells.”

The above comment also relates somewhat to Claim #5, that participants base their products around market research instead of what works.

Claim #7: Survey participants are producing different materials that provide more open-ended assessments for learning due to CCSSM.

Among the 14 comments coded that related to CCSSM, five comments related to assessments or tests. One participant noted that the tests students will take are “very different than the types of high-stakes test that you took as a student,” which, according to the participant, are more open-ended. One participant noted that among concerns in the industry, there are a lot of questions related to CCSSM and high-stakes tests, and there are still open questions on how this will pan out. All four participants in the study mentioned some concern about uses for assessing students with math tests and the opportunities that could be afforded with digital assessments.

Claim #8: Survey participants’ companies at which they are employed are producing a blend of educational technology products and print products due to not all teachers adopting digital platforms.

As mentioned in Claim #5, the comments in the data reflected a blend of products that are being produced for the educational marketplace. For example, a first participant noted that they make their content available as both downloadable PDFs and also tablet components to address different needs of schools. A second participant said that "schools are very slow to adopt digital content even though many students have access to iPhones and mobile devices [...] When we build products, we make [our products] digital but make accommodations for those who don't [use digital]." A third participant produces print books, digital books, online video content, and online classes to reach different students. A fourth participant makes online math apps for tablets but noted that the company's mathematics department produces print workbooks, too.

Claim #9: Survey participants are working towards adaptive content that provides constant feedback.

Because of digital platforms, participants noted that the direction that future educational products are heading is towards adaptive digital content. Participants are addressing this in various ways. One participant noted, "Our company is moving into gamification because want to make education fun. The idea is so we can borrow what we see with varying success. It is fun to see in different companies what is out there as companies shift across the entire industry."

Another participant said, "[The future is a] hard question—[the technology I am referring to is] called adaptive. Some technologies say they do it, [and it's] marketed like it's true. [There is a] project called Newton [that calls itself] adaptive content. We've worked towards adaptive content, [but I am] not sure about [the] initiative behind it because [it's] so hard to do."

Claim #10: Survey participants' comments acknowledge that the educational companies' products examined are currently not standing up to NCTM CCSSM strands for grades six through eight math instruction.

In the comments I examined, participants' comments confirm what Meyer (2015) and EdReports.org claim, which is that in the participants' companies surveyed, the content inside mathematics digital products do not currently stand up to NCTM CCSSM standards for grades six through eight strands. One participant who works at company produces products that do not stand up to CCSSM standards because the company's mission is geared towards middle school math contests, not classroom instruction. A second participant admitted that the company's digital product does not meet requirements according to EdReports.org, and the company is working to fix that for future reports. A third participant noted that the product does not need to focus on changes due to Common Core as much compared to other places because they are a newer company. The fourth participant said that in the initial intake of a customer, the company looks at how the school lines up with Common Core or State Standards, then students may use their product to advance to grade level math.

Claim #11: Survey participants are anticipating Common Core digital assessments, but otherwise seem unmoved by CCSSM for content development.

Although participants talked about CCSSM standards being important for future directions, they overall seemed less concerned about how CCSSM would change their own content development process. One noted that the company does check for CCSSM during department meetings, but that was not the crux of the participant's creation process. Another noted that problem-based learning is scaffolded with CCSSM anyway. A third participant noted that the company checks for education effectiveness, but according to the company website, success is measured by the company's strand, not CCSSM. EdReports.org was discussed in one interview, in which the participant noted that the company "hopes to be more rigorous" as a result of the product's report rating.

Discussion

Triangulating between the qualitative analysis, classroom discussions, my personal experiences as a middle school math teacher, and the literature discussed, the shift from print media to digital media as a technology provides many learning opportunities to transform the middle school mathematics classroom. In particular, educators have a chance to look at how we learn mathematics through the lense of CCSSM and create a completely new and engaging classroom with opportunities for student-centered classrooms. The role of a teacher is changing in this new classroom realm, and from my personal experiences, more professional development is needed to support that shift. Our classroom discussions conclude that we want to avoid excessive individualization and personalization, and to instead use technologies to support communication, social practices, and collaboration with others in the digital as well as in-person realm. Providing workspace canvases that support this realm will also promote deeper learning as well as best mathematical teaching practices.

In general, the educational publishing market is fragmenting as teachers are becoming advocates for what they want. On one hand, this change is good for the classrooms because unlike the past, teachers are no longer passively adopting a single textbook. Educators are also holding publishers accountable, as is shown in both the qualitative analysis claims and the emergence of sites such as EdReports.org. On the other hand, this poses scalability design questions for education, and since mathematics classrooms are hoping to create standards through CCSSM, this could also pose problems for how to address the changing needs. Comments in the qualitative analysis showed an openness to addressing market needs, which means that purchasers of digital content have power to consume educational products that also influence learning. Without a print textbook, teachers have options to create a truly dynamic twenty-first century math classroom.

Limitations

This report could be expanded in several ways. First, the literature covered could represent more middle school mathematics digital platforms and opportunities for learning mathematics through the lense of CCSSM standards. Second, with so many mathematics products being released every day, I likely only covered a small portion of educational products on the market. Future studies could benefit from more participant interviews, since I only had a small sample size. Given the timeframe of this research study, I cannot collect longitudinal data of the affordances for emerging digital technologies in the mathematics classroom. Finally, in the course of conducting this research analysis, I realized that my methods for collecting data could be improved. In particular I would have taped the interviews in order to collect more accurate data. I would have also revised my interview protocol to include less questions that gets at the crux of the larger issues in digital technologies and CCSSM.

Overall Assessment of the Digital Shift

My overall conclusions in the shift from print to digital media leaves me personally mystified. From class discussions, I envision many new and exciting possibilities for digital media in school, using technology to augment learning experiences through theories of learning through collaboration, sharing, reflecting, and problem-solving. My analysis of the strengths, limits, and recommendations for further direction follows.

Strengths and Limits. The strengths of the new technologies are that these digital platforms are easy to use, provide opportunities for quick dissemination, are easy to modify, teachers may remix content easily, and opportunities to purchase content “a la carte” allow teachers to proactively create a unique curriculum. The limits are that computing power in mobile platforms could be stronger in order to create a truly digital platform, teacher professional development, and creating content that truly aligns with CCSSM. Most barriers to widespread adoption include costs, textbooks that are already in place, schools being slow to adopt new technologies, teacher professional development, and scalability.

Recommendations for Future Direction and Implementation. Based on the research study, discussions with researchers[8], and the claims made in the qualitative analysis, my recommendations for future direction and implementation in emerging digital media for the middle school mathematics classroom follows:

Recommendation #1: Using theories of learning trajectories, we can support both learning standards and choices that support new theories of learning. Clearly from print media, implementing a single textbook leads to failure in adjusting for diverse learner needs and choices

[8] In particular, I base these recommendations from conversations synthesizing my research findings with J. Star (personal communication, March, 2015), C. Dede (personal communication, April 14, 2015), and imperatives suggested by J. Confrey at NCTM (personal communication, April 18, 2015)

in the middle school mathematics classroom. Creating the right digital platforms to support navigating learning trajectories through content standards will afford new opportunities for learning mathematics.

Recommendation #2: Support *doing mathematics* in the classroom to promote deeper learning, not rote memorization, and help students and teachers understand the purpose of math assessments. In thinking of mathematics itself as a tool, we want to think about how mathematics could be taught through a platform of open spaces, the ability to collaborate, and support sharing, data collection, recording, and problem-solving to help students. Digital environments could be used to provide classroom groups.

Recommendation #3: Use the classroom to model appropriate forms of collaboration. The role of a teacher, grouping methods, and many in-person and digital interactions afford opportunities for deeper learning. However, excessive individualization or teacher neglect is also something to be avoided with these new platforms emerging. As mentioned during class discussion, in order to learn how to collaborate in the classroom, we could provide opportunities for digital as well as in-person interaction as part of the social development process for adolescents.

Recommendation #4: Continue to support student progress. With new data trends emerging, learning analytics, stealth assessments, formative digital assessments, and high-stakes tests can provide many opportunities for feedback (see Fishman & Dede, 2015). J. Confrey noted that in the classroom, assessments could be positioned as supporting positive and necessary feedback instead of harsh criticism of progress (personal communication, April 18, 2015).[9]

Conclusions

[9] Perhaps the best analogy I came across that speaks to this recommendation comes from A. Benjamin: "What does a dog, a math student, and health care patient have in common? The dog can't choose his food, the math student can't choose his book, and the health care patient can't chose his medicine." (personal communication, March 2015).

Walking around the NCTM National Exposition hall inside the Boston Convention Center last April, I found myself swimming across hundreds of booths flashing platforms, manipulatives, digital games, and calculators, all claiming to revolutionize teaching and learning mathematics in the classroom. As I reflected on the research synthesis, I thought about C. Dede's comment that most of innovation lies in education, not the technology component (personal communication, January 26, 2015). With so many digital mathematics tools on the market, the next hurdle that mathematics instruction has to overcome is teacher professional development and recruiting mathematics teachers who can deliver content that meets CCSSM standards. As Fishman & Dede (2015) report, most of the barriers to these new technologies are "not conceptual, technical or economic, but instead psychological, political, and cultural" (p. 145). This viewpoint is further compounded with some of the psychological barriers surrounding mathematics instruction (see Boaler, 2015). Going forward, I hope to realize and implement the potential change that new digital technologies can afford in the mathematics classroom, and I hope that the larger shift to new mathematical standards as well as digital platforms creates opportunities, not limits, to middle school mathematics education.

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Table 1

Categorization of Qualitative Data Collected

For qualitative data, I categorized the content based on industry concerns,[10] industry topics, and participant attitude. The following tables show the categorizations:[11]

Code	**Concern**	**Description of Category**	**Example 1**	**Example 2**

[10] *Note:* Comments surrounding CCSSM were coded using colors and highlighting instead of the table figures.
[11] *Note.* I base the table figure from a qualitative analysis handout in T523: Formative Evaluation for Educational Product Development taught at Harvard GSE, Spring 2015 (C. Reich, personal communication, March 6, 2015). Example comments are entirely fictional and are not based on a specific person.

A	Changes in the Industry	Includes comments relating to how the industry has changed in the past 5-7 years.	“There has been a lot of changes in how we manage /	“We haven’t seen the impact of these changes yet”

B	Competition	Includes comments relating to publisher company concerns relating to competition and threats to the company.	“I know that MathAwesome released a product last fal	“We’ve been getting a lot of inquiries about a new start-up product in the area.”

C	Customers	Includes comments about how the company relates to customers, customer support, and concerns relating to customers.	“I still can’t believe this person didn’t know wha	“Most our customers report they are comfortable working with us.”

D	Dissemination	Includes comments relating to disseminating the product to customers and publication process.	“...we now publish our content online.”	“Teachers express concerns accessing the product (don’t know where Downloads folder is located on computer).”

E	Ethics of Company	Includes comments related to ethics of company practices.	“We felt hypocritical distributing this product, bu	“We will only create quality educational products because teaching math is our first priority.”

F	Future trends	Comments related to future products and speculation about where the industry will go.	“We are currently working to develop a new . . .”	“We think that the next step is . . .”

G	Innovation vs. Traditional Approaches of Company	Includes comments about how the company responds to creating solutions.	“We are creating new products every day.”	“Our bestselling product is about 15 years old and on its seventh edition.”

H	Outlook of industry	Includes comments related to the person’s take on the industry.	“I’d say as a collective we responded to the demand	“I’m pretty upset with how the industry has stacked up after the print to digital content shift.”

I	Publisher’s Research Methods / Knowledge of the Literature	How the company responds to literature	“We tend to create products based on our own resear	“Math has been the same for 300 years, and we’re not changing that.”

Code	**Topics**	**Description of Category**	**Example 1**	**Example 2**

1	Content	Comments related to developing content.	“Jane is our content developer and I enjoy working with	“We work together to produce quality content first.”

2	Marketing / Sales	Comments related to marketing / sales branch of industry.	"Our marketing campaign last year focused on . . ."	"Our sales reps tend to . . ."

3	Math	Includes all comments that concern math education in general, or more specific parts about math education that do not fit in other categories	"We love math!"	"Math education itself is facing an overhaul."

4	Non-math	Includes all comments that do not involve the math publishing industry, such as English curriculum comments	“We have a really awesome Shakespeare curriculum co	“Our history curriculum was published last year, and we

5	Publications / Products	Includes all comments about publications and products.	“Our newest product, TrendyMath, features some key dynam	“We do still publish math textbooks, such as Smith et.

6	Website / Promotions	Includes thoughts about the publisher website, newsletter, online tools, brochures, trade shows, etc.	“We just launched a new website, and we’re excited ab	“Most our customers find us through our monthly newslett

Code	Attitude	Description of Attitude	Example 1	Example 2

P	Positive	Includes all comments that discuss positive experiences in publishing industry.	"I always enjoyed my job as a curriculum developer."	"It's really great dealing with our client base."

N	Negative	Includes all comments that discuss negative experiences in publishing industry; also includes comments that suggest needed improvement or opportunities to improve.	“It would help if we could spend more time measuring	“We're still stinging from our competitor's new produc

O	Neutral	Includes all comments that are neither positive nor negative tone, includes new ideas for industry, questions about study, etc.	“We’ll be ready for π Day next year.”	“We’re hoping to explore opportunities in Texas this s

Table 2

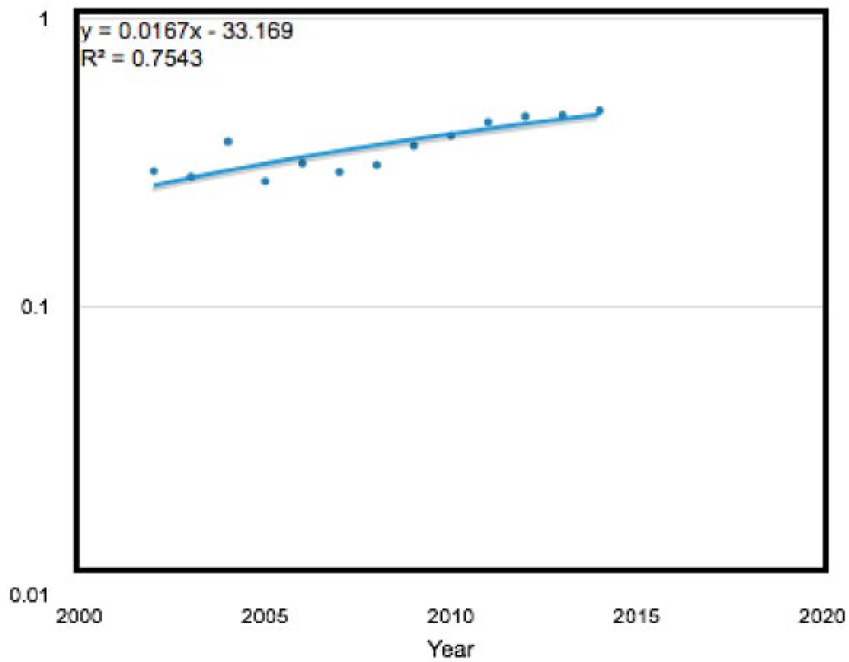
List of Digital Technologies Surveyed

Company or Product	**URL**
Amplify	http://www.amplify.com/
Art of Problem-Solving	http://www.artofproblemsolving.com/
Basic Books	http://www.basicbooks.com/
BrainQuake	http://innertubegames.net/
CENGAGE Learning	http://www.cengage.com/us/
Center for Game Science	http://play.centerforgamescience.org/refraction/site/
Center of Mathematics	http://centerofmath.org/
Clever	https://clever.com/
CoolMath-Games.com	http://www.coolmath-games.com/0-mancala
Curriculum Associates	http://www.curriculumassociates.com/
Dan Meyer’s Three-Act Math Tasks	http://threeacts.mrmeyer.com
Desmos Math	https://www.desmos.com/
DragonBox	http://www.dragonboxapp.com/
Dreambox Learning	http://www.dreambox.com/
Edmodo	https://www.edmodo.com/
Education Development Center	http://www.edc.org/
FASTT Math	http://www.scholastic.com/fastt-math/
Google Docs, Google Drive, LaTeX for Google	http://drive.google.com/
Great Courses DVDs	http://www.thegreatcourses.com/

IXL Learning	http://www.ixl.com/
Company or Product	**URL**
Khan Academy	https://www.khanacademy.org/
Lure of the Labyrinth	https://labyrinth.thinkport.org/www/
Mathbreakers	https://www.mathbreakers.com/
Math Solutions	http://mathsolutions.com/
Math Twitter Blogosphere	https://twitter.com/hashtag/mtbos
McGraw-Hill Education	http://www.mheducation.com/
Motion Math	http://motionmathgames.com/
NCTM Illuminations	http://illuminations.nctm.org/
Pearson	http://www.pearsoned.com/prek-12-education/
Pearson Efficacy	http://efficacy.pearson.com/
Reasoning Mind	http://www.reasoningmind.org/
Renaissance Learning, Inc.	http://www.renaissance.com/
Scholastic, Inc.	http://www.scholastic.com/home/
Snapwiz	http://snapwiz.com/
SUDDS	http://sudds.ced.ncsu.edu/
TERC: Zoombinis	https://www.terc.edu/display/HOME/Home
TurnOnCCMath.net	https://turnonccmath.net/
Wolfram Alpha	http://www.wolframalpha.com/

Figure 1

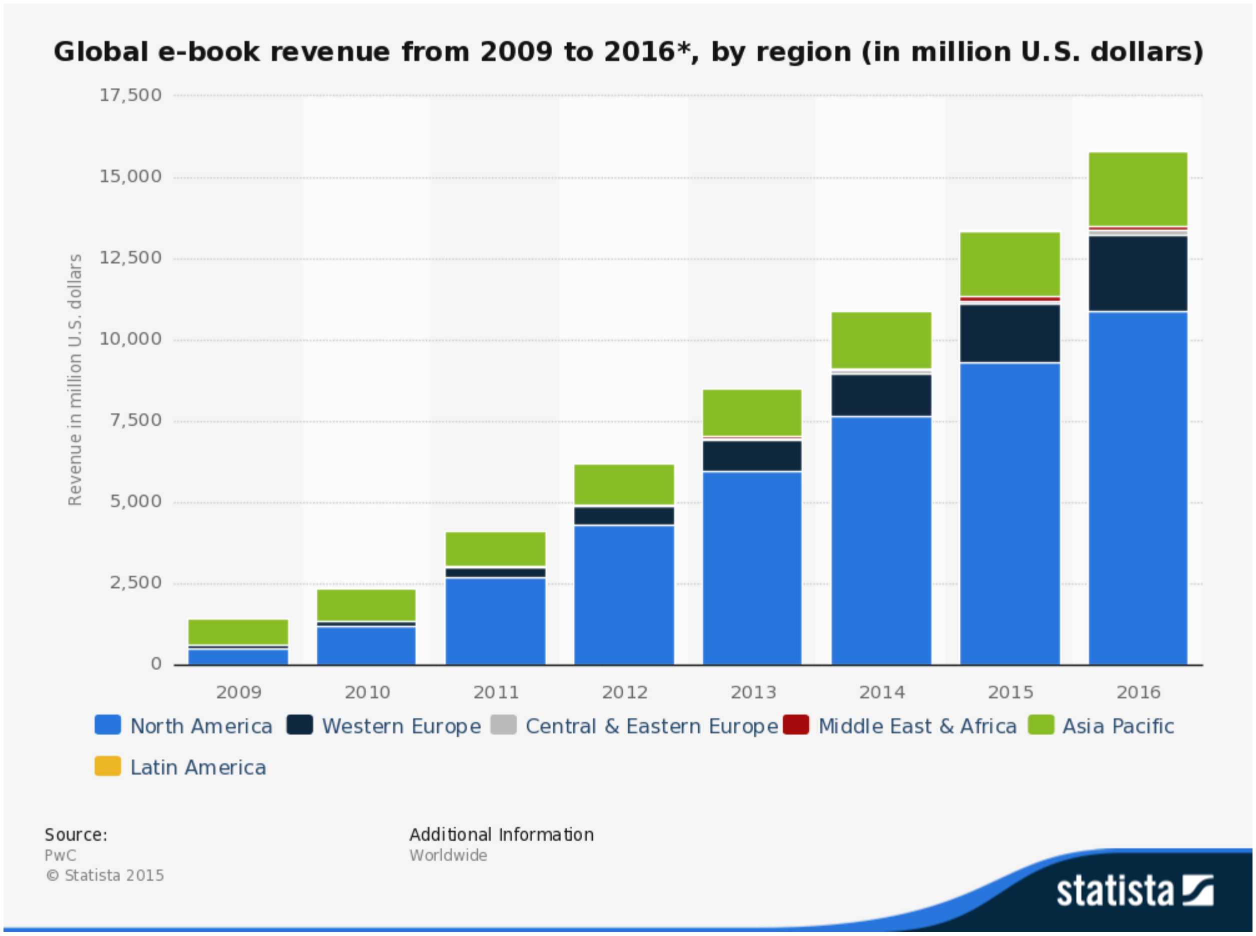
Digital versus print content in the PreK through 12 Publishing Market[12]



[12] Sources for market share come from Simba Information Reports, 2002-2015, Retrieved from MarketResearch database. See Mickey & Meaney (2014) for one citation listing.

Figure 2

Global e-book revenue from 2009 to 2016, by region[13]



13 Source: Statista (2015), retrieved from http://www.statista.com/statistics/304243/global-print-and-e-book-revenue-by-type-consumer-educational-professional/

Appendix A

Interview Protocol

Template for Initial Email to Participant:

Dear _______________,

My name is Natalya St. Clair and I am a student at Harvard Graduate School of Education (HGSE). I received your contact information from [*my professor, Chris Dede* or *the contact information listed on your company website*].

As part of my studies at the HGSE, I am currently enrolled in T561: Transforming Education Through Emerging Technologies. In this course we examine theory and application of new technologies. As part of a semester-long project, I am performing an interview study to find out what a future middle school math classroom looks like, and how publishers are responding to it.

I am asking permission to interview you for about 30 minutes. The interview consists of two parts: first, I will ask some information about current and past projects you are involved in and second some questions about these particular projects.

I will summarize and share my findings from this interview only with my professor and teaching fellows in this course. Neither your identity nor your company will be disclosed when I write up my report. Your participation will be completely voluntary, which means you may withdraw at any time in the study. I do not foresee any potential risks or discomfort as a result of participating in this study.

Before we begin, I will need you to fill out an Informed Consent form, which I have attached in this email. If you have any further questions, please do not hesitate to contact me.

Thank you,

Natalya St. Clair

Part 1: Background data

Name: Age:

Location of Interview: Medium used to conduct interview:

Date: Approximate duration of interview:

Job title, company (time allowing)

Ask: "Could you tell me about what you do here?"

Job title:

Company:

Location of company:

Size of company:

For-Profit / Not for-profit:

Estimated job description in organization of publishing company:

Approximate length of employment for the company

Ask: "About how long have you been working at -------?"

Part 2: Description of Current Projects

i. *Learn about current projects:* Could you talk to me about one project that comes to mind that is related to a grade 6-8 math classroom?

   i. Overall, what has been your experience with this project?

   ii. Overall, how has it been the same or different from past projects?

ii. *Learn about technology component:* What changes, if any, have you seen while you worked here? Can you tell me about an instance of this that comes to mind?

   i. [Probe]: How has the industry in general responded to current trends in educational technology?

Part 3: Description of Future Projects

- *Learn about current projects in production.* Could you tell me about how the organization creates or maintains a new technology for mathematics education?
- When you look at what the state of mathematics education is like today, where does [company] fit?
  - [probe] Where is the level of that now? How fast do you think we are moving towards it?
  - [probe—clarify] So you're talking about -----. How soon will we be there?
  - How do we get people to use [this technology] more?
- *Learn about future trends.* What do you think will be some big changes in the next five to ten years of the publishing industry for mathematics education? How does this align with the company's goals?
  - [probe] What kind of things keep you up at night? What concerns do you have about the industry?
  - [probe] Where is the company going next?

Part IV: (Time Allowing)

i. *Learn about research methods being used to develop curriculum:* Can you tell me about how the organization creates or maintains a new middle school math curriculum?

    i. Overall, how has it been the same or different from past projects?

    ii. How do you find evidence for decisions to make when developing a project?

    iii. How do you decide what content should be included?

        i. [Probe] Where would you go to base some of this evidence?

ii. *Learn about innovation vs. traditional approaches:* How do some of the projects we've talked about align with the goals of the company?

iii. *Learn about effective products vs. selling products.* Could you describe a project that in your view was highly successful? How was the product received?

Closing: It's great to talk to you, and a pleasure to discuss things with you. Thanks, --------.

Appendix B

Consent Form

Study Title: Course Project for T561: Transforming Education Through Emerging Technologies

Researcher: Natalya St. Clair

Participation is voluntary

It is your choice whether or not to participate in this research. If you choose to participate, you may change your mind and leave the study at any time. Refusal to participate or stopping your participation will involve no penalty or loss of benefits to which you are otherwise entitled.

What is the purpose of this research?

The purpose of this research is to find out what a future middle school math classroom looks like, and how publishers are responding to it.

How long will I take part in this research?

Your participation will involve one 30-minute interview.

What can I expect if I take part in this research?

As a participant, you will answer some information about current and past projects you are involved in and answer some questions about these particular projects.

What are the risks and possible discomforts?

There are no potential risks or discomfort as a result of participating in this study.

Are there any benefits from being in this research study?

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits for educators include furthering understanding of mathematics instruction and how content is being developed.

If I take part in this research, how will my privacy be protected? What happens to the information you collect?

The findings from this interview will be shared only with the professor and teaching fellows in this course. Neither your identity nor your company will be disclosed. Your participation will be completely voluntary, which means you may withdraw at any time in the study. All audio recordings collected from the interview will be transcribed with names and companies altered and deleted promptly afterwards.

If I have any questions, concerns or complaints about this research study, who can I talk to?

If you would like to talk to the research team, the researcher for this study is Natalya St. Clair who can be reached at (617) 821-5374, 13 Appian Way, Cambridge, MA 02138, nms409@mail.harvard.edu. The faculty sponsor is Chris Dede who can be reached at chris_dede@gse.harvard.edu.

This research has been reviewed by the Committee on the Use of Human Subjects in Research at Harvard University. They can be reached at 617-496-2847, 1414 Massachusetts Avenue, Second Floor, Cambridge, MA 02138, or cuhs@fas.harvard.edu for any of the following:

If your questions, concerns, or complaints are not being answered by the research team,

If you cannot reach the research team,

If you want to talk to someone besides the research team, or

If you have questions about your rights as a research participant.

Statement of Consent

I have read the information in this consent form. All my questions about the research have been answered to my satisfaction.

SIGNATURE

Your signature below indicates your permission to take part in this research. You will be provided with a copy of this consent form.

____

Printed name of participant

____ ____________________

Signature of participant Date

Appendix C

Eleven Research Claims and Four Recommendations

Research Claims

i. A twenty-first century math classroom emphasizes creative problem-solving, mathematical modelling, opportunities for collaboration, and mathematical fluency as outlined by CCSSM.

ii. There is no typical twenty-first century math classroom due to scalability design in education.

iii. Educational product consumers are becoming more selective and outspoken about their classroom individual needs than in the past.

iv. Survey participants envision a connected middle school math classroom with immersive digital experiences.

v. Survey participants base their products around market research and communication with customers.

vi. Survey participants focus on school and student needs and hold themselves accountable for these needs.

vii. Survey participants are producing different materials that provide more open-ended assessments for learning due to CCSSM.

viii. Survey participants' companies at which they are employed are producing a blend of educational technology products and print products due to not all teachers adopting digital platforms.

ix. Survey participants are working towards adaptive content that provides constant feedback.

x. Survey participants' comments acknowledge that the educational companies' products examined are currently not standing up to NCTM CCSSM strands for grades six through eight math instruction.

xi. Survey participants are anticipating Common Core digital assessments, but otherwise seem unmoved by CCSSM for content development.

Research Recommendations

i. Using theories of learning trajectories, support both learning standards and choices to promote design for standards and scalability.

ii. Support *doing mathematics* in the classroom to promote deeper learning, not rote memorization, and help students and teachers understand the purpose of math assessments.

iii. Use the classroom to model appropriate forms of collaboration.

iv. Continue to support student progress.