LEADERSHIP IN MATHEMATICS EDUCATION
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National Council of Supervisors of Mathematics

CoSN
LEADING EDUCATION INNOVATION

Consortium for School Networking

Mathematics Education in the Digital Age

Reform in mathematics education and the rise of digital learning represent two growing movements in our nation's school leadership, policies, and practice. Heightened national focus on mathematics education is leading to long-anticipated agreement on standards and practices, and increased efforts in school districts to help our students excel. The digital revolution is transitioning our schools from paper-rich to technology-and-media-rich learning environments. In the midst of these changes, a big issue arises: Technology in schools can either accelerate the momentum in mathematics education or undermine that momentum. On one hand, technology can help students visualize and comprehend mathematics, while their teachers gain deep insights into student cognition and share their professional growth with a web-connected community. On the other hand, technology can water down mathematics into competitive, drill and practice games for students, while relegating teachers to the role of computer proctors who are disengaged from their role in helping students to learn and grow.

Recognizing a need for vision and guidance, the National Council of Supervisors of Mathematics (NCSM) recently convened a Digital Learning Visioning Committee to examine the future of quality mathematics education in the digital age. Recent NCSM initiatives set the stage for this effort. In 2007, the PRIME Leadership Framework described professional practice in mathematics leadership for grades K–12. In 2014, *It's TIME—Themes and Imperatives for Mathematics Education* provides guidance for the successful implementation of the new national and state mathematics standards which emphasize deep conceptual understanding of mathematics and the connection of mathematics to everyday life. The Digital Learning Visioning Committee determined that the continued pursuit of excellence in mathematics education can best be secured by proactively raising challenging issues about technology integration and teaming with instructional technology leaders to address those issues.

This paper summarizes the work of the Visioning Committee to date, incorporates input from representatives of the Consortium for School Networking (CoSN), and initiates the planning process intended to optimize mathematics education in the digital learning era. It focuses on two pillars of mathematics education: Student Learning and Professional Learning. It identifies the opportunities and threats that digital integration presents, and it offers *resolutions* to be acted upon by leaders in both mathematics education and instructional technology. It discusses three *hot topics* that affect both student and professional learning: blended learning, motivation, and data. For each hot topic, the paper calls attention to *leadership challenges*, raising questions that must be addressed. Finally, it calls attention to political forces and funding decisions that will mold the future of digitally-enhanced mathematics education over the coming years. This paper sets the stage for ongoing leadership work in mathematics education in the digital age.

Iris project
Focusing on digital mathematics education.

Mathematics Education in the Digital Age is presented as the first resource developed as part of NCSM's newest initiative: Iris project.

TWO PILLARS OF EDUCATIONAL QUALITY

Student Learning. Recent advancements in standards for mathematics education set a high bar. Students are now expected to make sense of mathematics, articulate their thinking, and attend to precision as they pursue rich math tasks. Schools and districts are called upon to deliver coherence in the curriculum, helping students build mathematical connections with careful task sequencing while fostering a classroom climate of engaging mathematical discourse. It is in this elevated context that educators must consider the role of technology-based resources and tools. Technology *must* strengthen the pillar of student learning.

Standards for technology integration in schools developed over the past 20 years have articulated the expectations for the 21st century learner. The ISTE Standards for Students (ISTE website, 2015) emphasize student-centered pursuit of knowledge and using technology to foster abundant interactions between inquiring minds. The SAMR model (Puentedura, 2015) offers a method of seeing how technology can go beyond a *substitution* of one resource for another and employ digital resources to eventually *redefine* the educational stimuli. The Universal Design for Learning (CAST website, 2015) research suggests that using technology to provide multiple means of representation, expression, and engagement leads to successful outcomes for differently-abled students.

The 21st century learning skills movement (p21 website, 2015) and the current mathematical standards movement share common goals. But, these goals are not always reflected in the deployment of technology in the mathematics classroom. Consider these underwhelming classroom realities:

- Students are using a PDF version of their textbook.
- Students who complete their math book assignment get to play a math game at the computer.
- Students who are struggling with a topic are directed to computer-based, drill-and-practice mathematics products that are essentially the flash cards of the past, with the addition of colorful graphics and rewards.
- The computer lab is being used to present procedurally-based mathematics curriculum to students, with no concerted effort in the school to engage students in deeper mathematical learning experiences.

Now is the time to fuel best practice in mathematics instruction with the power of digital learning. Consider these examples of excellence:

- Students are using technology and carefully-chosen websites to gather authentic data, engage with dynamic math models, and communicate their understanding of the world in mathematical terms.
- Students who are struggling with a topic are able to analyze their own performance data, choose from a variety of presentations and enabling technologies, and overcome their barriers as they engage with mathematics.
- School leaders are integrating and matching the right technology tools (labs, carts, tablets, graphing calculators, etc.) with appropriate learning targets.
- Students are collaborating and growing through web-based learning communities.

> **RESOLVED:** *Leaders in mathematics education and instructional technology must ensure that digital learning environments are* <u>*building upon*</u> *the established base of pedagogical practice and advancing excellent classroom instruction in mathematics in order to ensure more effective instruction and greater student achievement.*

Professional Learning. **As the tides of mathematics education and educational technologies rise, so rise the demands for quality professional development in both areas. Research strongly indicates a need to better prepare teachers in mathematics content knowledge** (National Mathematics Advisory Panel; Ball et al., 2008), **learning trajectories** (Clements & Sarama, 2004; Cobb et al., 2003; Confrey et al., 2012; Daro et al., 2011; Fosnot & Dolk, 2002; Fosnot & Jacob, 2010; Imm et al., 2012; Simon, 2006), **didactics** (Freudenthal, 1991; Gravemeijer, 1999; Brousseau, 1997; Lesh & Sriraman, 2010; Chevallard, 1992), **and pedagogical practice** (Kazemi & Hintz, 2014)**.** Increased rigor in mathematics standards is forcing school districts and university pre-service programs across the nation to answer the call. Much of this professional growth can be pursued through online learning and web-enhanced professional learning communities, as these venues offer a great wealth of resource and opportunities to interact with a national community of educators. At a minimum, teachers *must* gain the digital literacy required to employ the learning tools required for their classrooms. In this day and age, the intersection between professional learning in mathematics and instructional technology is getting larger.

Today, there is generally an absence of integration between mathematics and technology training for teachers. As a result, many educators are experiencing frustration and inefficiencies when learning optimal teaching techniques and deploying technology-based interactions in the classroom. Examples include:

- Some teachers and leaders feel isolated and unsupported in their attempts to engage in new, rich pedagogical practices in mathematics, even though many of their colleagues are engaged in online professional support dialogues.
- Some teachers find it difficult to successfully operate software and/or hardware when using technology to teach mathematics.
- Many interactive whiteboards and computer labs are underutilized in mathematics education because the professional staff, teachers and administrators are unprepared to take full advantage of these valuable resources.

CASE STUDY: *Professional Learning*

Takeaway: Leveraging face-to-face and online learning over time leads to deep understanding and professional engagement while reducing cost and time away from students.

Educator Statistics:

- 25 educators from across the United States and Canada
- Various school demographics represented.
- Various educator technology and tenure backgrounds represented.

Technology: Graphing calculators and instructional software

The Story: A group of mathematics educators wanted in-depth training on how best to implement new graphing technology in their classrooms. Given their geographic distribution and their desire to have some personal contact with their instructor, a blended learning experience was customized for them by T^3—Teachers Teaching with Technology. To kick off the training, they spent 2 days together with instructors Vince Doty and Katie Martinez. After the initial in-person event, they met once a month online using web-conferencing technology. Between these synchronous events, they implemented the graphing technology in their own classes, completed projects, and engaged in ongoing interactive dialogue with their instructors and peers.

At the end of the yearlong course, they came back together in person to celebrate their learnings, try their projects with one another, and push each other farther in their professional learning. Their instructor Vince Doty has years of in-person training experience as a T^3 National Instructor, and he commented that this class had learned more in this engagement than similar classes he had led with all in-person sessions. Those invariably did not have as many or as frequent touch-points due to time and budget. The class was such a success that this experience has been repeated with other classes and other instructor leaders.

By contrast, a well-integrated approach can deliver dramatic improvement. While technology innovations do not unilaterally deliver excellent mathematics professional development, they can greatly enhance the impact of knowledgeable professional guidance.

Imagine:

- Educators at all levels are using online professional learning communities, tools, and courses to enhance their mathematics content knowledge, pedagogical practice, and leadership.
- Educators are engaged in professional development that develops personal comfort with technology and the implementation of digital solutions for mathematics education.
- Teachers are able to leverage real-time and longitudinal performance data to inform instruction.

> **RESOLVED:** *Leaders in mathematics education and instructional technology must ensure that professional learning in mathematics education employs technology tools to build upon and advance leading practices, strengthen instruction, and improve student learning.*

THREE HOT TOPICS IN THE DIGITAL ERA

Blended Learning. *Blended learning* is an important movement in the evolution of classroom structures and digitally-enabled teaching environments. For years, teachers have been sending students to computer labs, using laptop carts, or working with a bank of computers in the back of the room. Today, the careful attention placed upon blended learning implementation provides the opportunity to be more deliberate in using integrated technology to achieve heightened educational objectives. Researchers have described specific blended learning structures including *station rotation*, *lab rotation*, *1:1 initiatives*, and the *flipped classroom.* Each of these models carries different implications for mathematics education which need to be analyzed going forward.

The blended learning movement also encompasses a philosophical shift in the relative roles of student and teacher. A pervasive thread is to encourage increase student agency, with a greater emphasis on student-centric learning environments and peer-to-peer collaborations as students matriculate from pre-kindergarten through grade 12. A second thread is to make more effective use of teacher time to address differentiated student needs. In theory, some students can be working with the computer or device while others are working in a focused manner with their teacher. A third thread is enabling asynchronous learning, where students and teachers can engage with a common stimulus and ensuing discourse without the requirement for being in the same place at the same time. Mathematics education can certainly improve as students become more self-directed and teachers take advantage of evolving classroom structures to mentor young mathematicians in workshop environments.

One of the reasons that blended learning is a hot topic is that the term has become a pop-culture catch-phrase referring to a range of imprecise implementation models. These models can lead to unintended consequences, including a lack of student engagement and teacher disempowerment in the mathematics classroom. A second reason is that questions are being raised regarding the future of the *brick and mortar* campus, especially for students in high school and perhaps middle school. Suggestions of educating students in mathematics in the absence of a teacher must be weighed against a powerful body of research on the positive correlation between teacher capability and student achievement (Picciano, Dziuban, & Graham, 2013).

LEADERSHIP CHALLENGES—*How can leaders in mathematics education and instructional technology …*

- *carefully study how blended learning practices influence student learning and then make informed decisions regarding the future of the blended learning movement?*
- *incorporate blended learning in professional learning for teachers, mathematics education specialists, administrators, university faculty, and all educators involved in mathematics education?*

Motivation. Two observations seem self-evident: First, technology tools have an inherent motivational and empowering impact on students. Second, many students do not feel motivated to engage with or excel in learning mathematics. Given these observations, it seems logical that infusing technology into mathematics education will increase enthusiasm for learning in many students. But, the concern is that there are differences between the stimuli sought by mathematics education leaders and the stimuli actually delivered by many of the existing technology solutions. These differences can potentially undermine quality mathematics education.

New mathematics standards and practices emphasize intrinsic motivation, in which students are engaged because they are building deep understanding, connecting mathematics to their daily life, and generally succeeding. Students are encouraged to learn through visual models and real life contexts, where the ultimate mastery of procedures is grounded in the meaning of big ideas and applied to rich math tasks. Research points to the lasting impact of educational experiences that use students' authentic data (Pink, 2011) and the impact that gaining deep understanding has on that each person's growth mindset (Boaler, 2013; Dweck, 2006a).

Many new, technology-based mathematics applications are emphasizing motivation through playful animations, competitions, and badges in the absence of coding strategies, strategies for using mathematical models, and real life connections. These computer-generated rewards can potentially augment a meaningful mathematical learning experience, but they can also dress up a shallow experience that skips

CASE STUDY: *Intrinsic Motivation Through Student-Centric Tasks*

Takeaway: Applying mathematics knowledge to a personalized task provides powerful intrinsic motivation, even for students who struggle.

District Statistics:

- Urban, public middle school in New York City
- Low-socio, mixed race district
- Self-contained 7th grade classroom with special education students

Technology: Early stage iPad adoption, one iPad Cart that can rotate.

The Story: The New York Hall of Science (NYSCI) is developing apps that invite middle school students to make mathematical discoveries in the midst of compelling design projects. Instead of using the game approach of motivating students through points or "power-ups," these apps rely on the intrinsic motivation of students of being "center stage" in their own personal design project. Students explore ratios and proportions using forced perspective photography, causing things to appear wildly larger or smaller than they are in real life. The tool provides onscreen props that students pose with, carefully adjusting their distance to change their image size in the photo. There are measurement tools to help students set up their shots and keep track of the data, as well as ways to share their photos, write about them, and even share their math and ratios.

In all of the classroom tests, students wanted to post their photos on social media, so engagement was clearly high, but observers also saw deep engagement with proportional reasoning. For example, one student in a self-contained special education classroom began using the distance meter and ratio tool to figure out the math behind his photos. To fit his friends into a virtual frame with window and door openings of different sizes, he used the tools to predict where his classmates needed to stand before they entered the frame. "I have to make you half your size so you need to double how far away you go." He wasn't always correct, but he was thinking in terms of ratios and later referenced the ratios in his story. His teacher was completely surprised to see this struggling student incorporating mathematics discourse into his creative process.

developmental learning and focuses upon procedural drill and practice. Compare these drill-and-practice math games to the learning experiences documented in Dr. Sugata Mitra's "Hole in the Wall" experiments (Mitra, 2015) in which students were motivated by their personal passions to collect data, understand the world, and accelerate their own learning.

Leaders in mathematics education and instructional technology must help school districts to make good choices when vetting mathematics applications and programs. The basis for the mathematics curriculum must be in the focus, rigor, and coherence demanded by today's standards. There is certainly a place for games, drill and practice, and competitions. But, these must be in service of a thoughtful curriculum that creates lasting learning experiences for all types of learners. The learning experiences need to focus on building deep understanding of mathematical concepts and use of the standards for mathematical practices, as well as skill fluency.

> **LEADERSHIP CHALLENGES**—*How can leaders in mathematics education and instructional technology …*
>
> - *help product developers to create applications that support focus, rigor, and coherence in mathematics?*
> - *evaluate applications for their ability to help students develop a balanced set of mathematical competencies using motivation strategies that support a disposition for lifelong learning.*

Data. The data around mathematics education is a hot topic for a number of reasons. The comparisons of international test scores in mathematics achievement have led to serious debates about best practice over the past 15 years. With the proliferation of online high stakes testing and instructional programs, much more student data is being captured than ever before. This student performance data is constantly analyzed and debated; from the classroom teacher, to the district administrator, to Washington, DC. Some say students are tested too much. Others say that data collection is obtrusive. Still others are thrilled with the potential to use a constant flow of big data to improve student outcomes.

The proliferation and access to data in education can be a two-edged sword and demands important leadership discussions around collection and use. Educators must decide what data needs to and does not need to be gathered and reported at the student, school, and district level. Strategic decisions must be based on the potential of a given set of data to inform system wide instructional decisions. Care must be taken so that the collection and reporting of data is not targeting low-level achievement skills and easy-to-capture "correct" or "incorrect" answers. In this era, where mathematical reasoning is being emphasized and technology innovation is on the rise, the educational leadership community needs to evolve data collection and reporting to encompass the analysis of student thinking, reasoning, and problem solving.

As student performance data in mathematics migrates from the static, paper-based past to the dynamic, web-based future, there are exciting implications for both formative and summative measures. Student learning can become more personalized, and students can use their self-awareness of their own performance as a fulcrum for personal improvement. Teachers can gain valuable insights into student thinking. Schools and districts can become better informed about the topics that require the greatest attention and the techniques that are yielding the best results. On a national level, summative data can steer educational policy in positive directions.

At the same time, student data can be used for other purposes that raise highly controversial issues, like evaluating teachers to determine their compensation or advancement. Data can be used to assess campuses or school districts, giving a thumbs-up or thumbs-down for programmatic funding. Data can be used to create clusters of students, tracking them according to perceived levels of performance. Teacher and campus evaluation, along with student tracking, are hot topics.

LEADERSHIP CHALLENGES—*How can leaders in mathematics education and instructional technology …*

- *ensure that the student performance data collected through online systems will be used in meaningful ways, with right-sized data collection efforts, to support student achievement in developmentally-appropriate ways?*
- *provide professional guidance in the collection and use of student data to university faculty, school administrators, and all educators involved in mathematics education?*

THE POLITICS OF CHANGE: MOVING FORWARD TOGETHER

Politics will play a huge role in both mathematics education and instructional technology as these two fields grow rapidly over the coming years. Politics will extend from the school board and community all the way into the classroom itself. There will be battles over allocation of funds, and there will be competition for human resources. For mathematics and instructional technology leaders, collaboration will be the key to success.

Going forward, planning around mathematics and technology funding and resource allocation will require political alignment between mathematics and instructional technology leadership. The negative ramifications of decisions made in isolation are all around us. There are ongoing examples of technology purchases that failed because they were made without a clear sense for educational outcomes. Digital content products are often purchased in an environment where the school or the school district simply does not have adequate devices or internet bandwidth to operate the program. Sometimes, even when both the hardware devices and software are well-chosen, there is inadequate allocation of instructional technology staffing for successful implementation. We must solve these problems on a structural and political level. The starting point is to have a strong working relationship between mathematical leadership and instructional technology leadership.

The digital era of education has begun, and leaders in math education and instructional technology must take action, together. In the midst of standards debates, and in the midst of evolving technology formats and operating systems, leaders must advocate for the thoughtful adoption of educational resources and the careful allocation of financial and human resources. This paper represents a beginning, where the National Council of Supervisors of Mathematics (NCSM) and the Consortium for School Networking (CoSN) are working together to define the issues we collectively face and express a shared determination to provide leadership and resolve to shape the future of mathematics education in the digital age.

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