Preliminary Guidelines for Using Interactive Mobile Technologies in Early Elementary Mathematics

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Introduction
Interactive mobile technologies such as iPads, Chromebooks, and other handheld computing devices are becoming increasingly pervasive in K–12 classrooms in the United States. How can these tools be used to support ambitious learning and teaching goals, particularly in mathematics in the early grades?

In November 2014, 35 education researchers, district and school leaders, and teachers met in Auburn, Maine, as part of the Research + Practice Collaboratory, a five-year project funded by the National Science Foundation to share knowledge and ideas about the opportunities that interactive mobile technologies currently offer to support mathematics learning among young students. Focusing on learning and teaching issues rather than on technology infrastructure requirements, participants at the Interactive Mobile Technologies Inquiry Group, or ITIG, also discussed the learning approaches and arrangements that may be needed to maximize these opportunities. From this meeting emerged a set of preliminary guidelines to promote mathematical thinking among young students with access to interactive mobile technology in their classrooms. This report presents these guidelines, the rationale behind them, and additional resources.

Auburn, Maine, is currently the site of a collaborative effort among public-school teachers and administrators; the Interactive STEM team at EDC, which is a major partner in the Research + Practice Collaboratory; and Maine university researchers to investigate and build local capacity in the use of one-to-one iPads to support mathematics learning in grades K–3.

Auburn is also the home of the Leveraging Learning Institute, an annual conference organized by the Auburn School Department to support educators from around the country who are implementing iPad initiatives in their classrooms. The ITIG meeting was held in Auburn to involve educators and researchers participating in the Auburn district collaboration and the November 2014 Leveraging Learning Institute.

The 35 participants at the meeting included 13 teachers, principals, and district leaders and 22 researchers and technical assistance providers. Table 1 shows the participants by role, and Appendix A lists their names and affiliations. Seven of the 13 Maine educators and 12 of the 22 researchers and technical assistance providers have been involved with the Research + Practice collaboration in Auburn or with the Collaboratory project more broadly. Visit the Interactive STEM website to view reports on the strategies used at the ITIG meeting to elicit the preliminary guidelines and to learn more about participants’ experiences.

The mathematical thinking that the preliminary guidelines aim to foster includes conceptual understandings of mathematical ideas and the display of core mathematical practices as outlined by the Standards for Mathematical Practice from the Common Core State Standards. Readers should view these guidelines as a “beta” resource: They build on the research evidence and field experience shared by the meeting participants but will evolve as knowledge grows. The guidelines may also serve as broad conjectures that draw from prior research and current practice to guide further study.

Table 1. ITIG participants by role

<table>
<thead>
<tr>
<th>Role</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>School or district-based educators</td>
<td>13</td>
</tr>
<tr>
<td>Teachers</td>
<td>5</td>
</tr>
<tr>
<td>School principals</td>
<td>2</td>
</tr>
<tr>
<td>Math coaches</td>
<td>1</td>
</tr>
<tr>
<td>Technology coaches</td>
<td>3</td>
</tr>
<tr>
<td>District leaders</td>
<td>2</td>
</tr>
<tr>
<td>Educational researchers and technical</td>
<td>22</td>
</tr>
<tr>
<td>assistance providers</td>
<td></td>
</tr>
<tr>
<td>College or university</td>
<td>8</td>
</tr>
<tr>
<td>Non-university organization</td>
<td>14</td>
</tr>
</tbody>
</table>

Note: See the list of participants and their affiliations in Appendix A.

Development of the Preliminary Guidelines

In a series of panel presentations and small-group discussions over the two-day meeting, ITIG members explored multiple questions, such as:

» What are the affordances of using interactive mobile technology to support mathematics learning and teaching?

» What are key concerns and challenges in using these technologies to support the development of mathematical content and practices in K–3 classrooms?

» What design considerations for implementing these technologies have emerged from the experience, craft knowledge, and research shared during this meeting?

The ideas that ITIG participants shared were documented in slide presentations, video and audio recordings, and notes taken during small-group discussions. Before, during, and after the meeting, participants circulated resources relevant to the meeting’s topics (see Appendix B).

Drawing upon meeting discussions as well as these resources, meeting organizers summarized the major ideas that surfaced and drafted a set of guidelines for implementing interactive mobile technologies to support the development of mathematical thinking in K–3 classrooms. These draft guidelines were then sent to all meeting participants for review and comment. This report synthesizes the ideas and resources that emerged from this process.

The Preliminary Guidelines

Five broad guidelines arose from the insights shared during and after the meeting (Table 2). Guideline 1 focuses on understanding and making best use of the features of interactive mobile technologies that are well suited to promote mathematical thinking in young learners. Guidelines 2 and 3 describe the pedagogical environments that may be necessary to foster mathematical thinking with interactive mobile technologies. Guidelines 4 and 5 highlight the individual and organizational supports that teachers may need to enact guidelines 1–3.

Table 2. Preliminary guidelines for implementing interactive mobile technologies to support the development of mathematical thinking in K–3 classrooms

| 1. Take advantage of the affordances of interactive mobile technologies to support conceptual learning. Key affordances include digital technology’s capacities to: | a. Provide dynamic, multisensory representations of mathematical ideas.  
b. Record and respond to user data.  
c. Make student thinking visible and more widely shared.  
d. Facilitate shared learning activities. |
|---|---|
| 2. Keep learning at the forefront: | a. Know the learning goals.  
b. Understand relevant learning progressions.  
c. Understand uses and activities that are developmentally appropriate.  
d. Integrate digital with nondigital activities.  
e. Provide opportunities for thoughtful, reflective practice. |
| 3. Create a classroom culture of exploration and sharing: | a. Encourage students to take risks and persist in the face of challenges.  
b. Set norms by which students can take the lead in their learning.  
c. Support students in building knowledge from what they already know.  
d. Foster collaboration. |
| 4. Provide teachers with supports to use new tools and to transform instruction: | a. Offer opportunities to learn math content, math practices, and new technologies.  
b. Promote teacher learning through collaboration with peers.  
c. Enable teacher learning through small, iterative steps, ongoing over time.  
d. Envision adults as facilitators of learning. |
| 5. Establish organizational arrangements to support effective use of technology: | a. Build adequate time for math instruction with interactive technologies.  
b. Facilitate regular access to research.  
c. Allow alternate teaching arrangements.  
d. Ensure principal support for teacher development and classroom change. |
Guideline 1: Take advantage of the affordances of interactive mobile technologies to support conceptual learning.

At the ITIG meeting, several participants presented ideas about the unique attributes of interactive mobile technologies and the opportunities they offer to students to develop deeper understandings of mathematical concepts. These participants recommended that educators become familiar with the affordances of these technologies and take advantage of them in the classroom. Key affordances include digital technology’s capacities to do the following.

*Provide dynamic, multisensory representations of mathematical ideas.* Meeting participants discussed the dynamic, interactive digital tools that are available today on devices such as iPads and other computer platforms and that can help students build their mathematical knowledge. Like physical *manipulatives*, these digital tools or virtual manipulatives can help students see, hear, and physically interact with abstract mathematical concepts and processes through concrete demonstrations and tactile activities (e.g., with animations or games that relate the numeral 5 with a picture of five blocks or animals, or with illustrations that depict the process of addition by showing numerals change as objects are added to a group or a line). Such tools can help students develop deeper understandings of mathematical concepts by helping them access numerical quantities and relationships through varied representations.

Notably, digital tools or virtual manipulatives can be even more powerful than their physical counterparts. Meeting participants described how digital technologies can overcome constraints of space and time in the classroom. For example, digital simulations can depict minute amounts as well as extremely large quantities; distances near and far; and long-term change processes, such as aging or decay. Screen technologies can aid student learning by providing multiple representations of mathematical concepts, and they can also help to focus students’ attention on mathematical processes. For example, a Web program might require students to rotate and manipulate a set of geometric shapes before solving a problem with the shapes, thereby helping students to focus on the problem’s geometric concepts and transformations. Screen applications such as open number lines and number racks can also serve as general-purpose, flexible, and dynamic tools that students can use to approach a variety of mathematics problems. (See the resources in Appendix B, section 1.a.)

*Record and respond to user data.* Another important affordance of interactive mobile technologies is the capacity to capture students’ verbal and behavioral responses to tasks or problems and the potential this offers as a scaffold for furthering student learning. Meeting participants stressed the importance of observing students’ strategies at solving problems rather than the answers alone. Digital tools and devices collect a continuous stream of data that may then be used to guide students’ attempts to navigate new mathematical terrain. Because the path along which students learn new mathematical concepts may not be linear, digital recordings of how students approach problems can provide teachers and students—as well as “intelligent” adaptive learning systems on the devices themselves—with detailed information to clarify the barriers students may face as they learn. Interactive mobile technologies therefore offer important aids for gathering and managing data about the complex pathways students may take as they try to master mathematical concepts and practices. They also have the potential to provide individualized formative feedback to students based on the data received and to help guide adjustments to students’ ongoing learning experiences. (See resources in Appendix B, section 1.b.)
Make student thinking visible and more widely shared. Several meeting participants who are current classroom educators described the positive student responses they observe when students use recording devices through educational apps or the iPad camera to document their problem-solving approaches and to share their thinking with others. Multisensory recordings allow students to review, reflect on, and critique their own as well as other students’ text-based, pictorial, or spoken artifacts. The ease with which recordings can be shared exposes students to different ways to solve problems and allows them to spot and often correct their own misconceptions and errors. The ability to produce video and audio recordings of their own work can help students view themselves as creators of their own mathematical ideas and can be highly engaging. When repeated over time, recordings of students’ mathematical thinking can provide students with proof of their own learning and may offer encouragement and fuel motivation. (See resources in Appendix B, section 1.c.)

Facilitate shared learning activities. Meeting participants and the resources they distributed emphasize the important role that social interactions play in learning and how interactive mobile technologies can provide engaging ways to facilitate shared learning activities. Participants described the value of having students interact with digital media in conjunction with other students or adults. Significant learning can occur when students play games, work together to solve problems, and create new ideas or solutions in shared digital spaces. Interactive mobile technologies can provide dynamic mathematical stimuli around which students may collaboratively engage, and they can support the sharing and distribution of student work that are often needed for productive collaboration. (See resources in Appendix B, section 1.d.)

Guideline 2: Keep learning at the forefront.

Meeting participants emphasized that interactive mobile technologies can play important roles in mathematical learning only when learning goals are clear and technologies are strategically harnessed to support these goals. Mathematical learning does not arise when students simply have access to new technology tools; teachers must help establish learning targets for students and know when and how to integrate technology to support achievement of these targets.

Know the learning goals. A recurring theme throughout the meeting was how critical it is for teachers to have a clear understanding of the mathematical learning goals they want students to achieve. Without such understandings, it is less likely the technology used in the classroom will support strong student outcomes. New interactive digital tools and mobile apps are continually coming online to serve different purposes. Working in contexts awash with digital choices, several Maine educators described how important it is for educators to evaluate and select these new digital tools to maximize alignment with learning targets. (See resources in Appendix B, section 2.a.)

Understand relevant learning progressions. Reaching a learning target is typically a multistep process, and the paths that students take vary. Meeting participants reflected on the learning trajectories or pathways students take on their way to learning mathematical concepts, ideas, and practices. Educators need to understand what the milestones may be for different learning targets to select the digital tools that can best support students in meeting these milestones. (See Appendix B, section 2.b.)

Understand uses and activities that are developmentally appropriate. Just as it is important for teachers to choose and integrate digital tools aligned with student learning goals, it is
important for teachers to select tools that match where students are in their cognitive, socio-emotional, or physical development. Meeting participants raised the point that some screen representations and activities can be enlightening for some students but distracting or cognitively overwhelming for others. Even when teachers identify specific digital resources that are appropriate for the learning goals and developmental stages of individual students, they may still need to help students focus on the most important components of the digital activities to prevent distraction from core mathematical tasks. (See Appendix B, section 2.c.)

Integrate digital with nondigital activities. Meeting participants observed a limit in how much students may stay engaged with digital tools as part of mathematics lessons. Teachers need to mix on-screen time with off-screen time (including discussion, movement, written expression, and manipulating physical objects) to keep young students engaged and focused on learning. Based on current research, one participant recommended a 5-to-1 ratio of nondigital to digital activities in the classroom. (See Appendix B, section 2.d.)

Provide opportunities for thoughtful, reflective practice. Meeting participants noted the importance of repeated practice in student learning but also acknowledged a downside when repetition triggers disengagement and turns off student thinking. Digital technologies provide students with the opportunity for repeated practice, keeping their minds “on” by presenting ideas from multiple perspectives. Teachers, however, may wish to look for or tailor screen activities to promote more reflective practice. (See Appendix B, section 2.e.)

Guideline 3. Create a culture of exploration and sharing.

To maximize the opportunities that technology offers to support strong mathematical thinking, educators need to create and support classrooms where students are expected to investigate, explore, invent, and generate mathematical ideas—both on-screen and off-screen, independently and with peers. Participants suggested that interactive mobile technologies cannot take the lead in developing young mathematical thinkers, but they can play an important supporting role when classroom foundations are in place.

Encourage students to take risks and persist in the face of challenges. Multiple meeting participants agreed that risk-taking and persistence in struggle are necessary for solving mathematical problems and the development of strong mathematical thinking. They suggested that students and teachers will not realize the full benefits of interactive mobile technologies in mathematics learning unless habits of risk-taking and persistence are embedded in daily work and applied to digital screen activities. (See Appendix B, section 3.a.)

Set norms by which students can take the lead in their learning. To develop strong mathematical thinkers, teachers need to let students follow their own interests and come up with their own solutions as they explore mathematical ideas and problems. This approach should also apply in the use of interactive mobile technologies: students should be given some freedom to play with digital tools and applications to engage their thinking during mathematical activities. Empowering students to explore mathematics with technology can help them see that knowledge and authority do not reside solely in the teacher or the

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3 For example, apps that allow students to change the colors and shapes of objects when engaged in counting activities may be helpful when such functions allow students to explore grouping patterns, but they may also prove distracting when such choices become activities in themselves and pull students’ attention away from the mathematical tasks at hand.
technology. Strong mathematical thinkers view themselves as agents in their own learning and mathematical problem solving. (See Appendix B, section 3.b.)

Support students in building knowledge from what they already know. To help students navigate new fields of learning, meeting participants discussed how teachers need to help students connect new ideas and activities with prior knowledge and experiences. As students explore mathematical concepts and problems using interactive mobile technologies, teachers need to provide a bridge between past and present mathematical tasks and tools to bolster students’ understandings and to keep them oriented toward learning goals. (See Appendix B, section 3.c.)

Foster collaboration. Meeting participants discussed research indicating that collaboration and social interactions can promote strong learning. Collaboration can help students see multiple perspectives, which in turn can help deepen understandings of mathematical concepts and ideas. As discussed above, interactive mobile technologies can facilitate shared learning experiences and collaboration by providing recording channels and digital spaces that allow students to share their work easily, and by providing activities in which students can distribute roles. (See Appendix B, section 3.d.)

Guideline 4. Provide teachers with supports to use new tools and to transform instruction.

Teachers play a seminal role in the classroom and need training to use technology effectively. This training cannot focus solely on learning how to use new technological tools, which can become obsolete very quickly. Teachers need to learn how new technologies may support or enhance student learning of specific content and practices and how to adapt and expand their pedagogical approaches to incorporate a variety of tools.

Offer opportunities to learn mathematical content, mathematical practices, and new technologies. To help students develop deep understandings of mathematical content and practices, teachers must have strong knowledge of the content and practices themselves and should therefore have opportunities to strengthen this knowledge where it is weak. Teachers also need to understand the trajectories that students may follow in pursuing specific mathematical learning objectives and to learn pedagogical approaches that can help students navigate these pathways. Further, when teachers have access to new technologies, they need guidance and practice in integrating these technologies into instruction and in learning how different digital tools may support different mathematical learning goals. (See Appendix B, section 4.a.)

Promote teacher learning through collaboration with peers. Meeting participants described how significant teacher learning can occur through collaboration with colleagues. They therefore recommended that schools and districts help provide and structure opportunities for peer collaboration that is focused on professional learning. (See Appendix B, section 4.b.)

Enable teacher learning through small, iterative steps, ongoing over time. Learning to teach in new ways with new and ever-evolving technologies can be a challenge. Meeting participants surmised that an effective way to help teachers change their instructional approaches to incorporate new technological tools productively is to support teachers in making small changes over time. Participants suggested that the time frames required for meaningful change are typically on the order of months or years rather than days or weeks. A more incremental process that includes opportunities for teachers to assess, reflect on,
and adjust new learning and teaching strategies with interactive technologies may lead to deeper understandings of what will work best with different students in their contexts and may promote more sustained changes in professional practice. (See Appendix B, section 4.c.)

_Envision adults as facilitators of learning._ Meeting participants noted that if the overarching goal is to promote students’ abilities to become independent mathematical thinkers, then teachers may need to learn how and when to be a “guide on the side” rather than to serve solely as a traditional “sage on the stage.” With the introduction of interactive technologies in the classroom, opportunities arise for teachers and students to work together in new ways and for students to engage in more active knowledge construction. For resources, see Appendix B, section 4.d.

**Guideline 5. Establish organizational arrangements to support effective use of technology.**

As new technologies become available for use in the classroom, organizational arrangements such as school routines, schedules, and staffing structures may need to change to help students and teachers take full advantage of the learning opportunities that the new tools bring.

**Build adequate time for math instruction with interactive technologies.** Meeting participants suggested that students need to be able to explore mathematical concepts and ideas to become mathematical thinkers and that such exploration requires time. Teachers and schools should therefore build in time for such activity during mathematics lessons, as well as time that may be needed for students and teachers to become familiar with new interactive technologies that can support mathematics learning but may require additional exploration to learn how to use. (See Appendix B, section 5.a.)

**Facilitate regular access to research.** Teachers and administrators at the meeting described their strong interest in current research and the guidance that it may provide to strengthen their daily work in learning and teaching. They noted, however, that they don’t have easy access to research literature or the time or capacity to read research papers—particularly those that are highly technical. And research organizations that publish practitioner-specific materials often charge fees that teachers must pay for themselves. Meeting participants encouraged both school and educational research communities to find ways to help teachers stay current with research on mathematics education and interactive technology and the practical implications they offer to improve classroom instruction. (See Appendix B, section 5.b.)

**Allow alternate teaching arrangements.** Mathematics teaching with interactive technology is most effective when teachers have knowledge and confidence in these domains. Meeting participants encouraged schools and districts to consider alternate teaching arrangements to help build teacher capacity and to deploy school assets in the most beneficial ways. For example, team teaching may help educators pool their strengths and work together to build professional knowledge. School leaders may also consider allowing teachers who have a particular passion or expertise in mathematics to focus on mathematics instruction in the early grades. (See Appendix B, section 5.c.)

**Ensure principal support for teacher development and classroom change.** As leaders who manage staff and set the overall vision of learning and teaching within their schools, principals play a critical role in supporting teachers who work on the frontlines to integrate new educational technologies in the classroom and to improve student learning outcomes.
Principals and other instructional leaders must understand and promote the many affordances of interactive technologies to enhance strong mathematical thinking in early grades, the learning and teaching strategies that can best develop such thinking, and the organizational structures that can allow such strategies to thrive. (See Appendix B, section 5.d.)

Conclusion
These guidelines are preliminary because they draw on knowledge shared among the participants at the Interactive Technologies Inquiry Group meeting in November 2014 but do not emerge from a comprehensive review of the literature nor a rigorous analysis of existing practice. Consequently, the guidelines can be seen as conjectures that may provide practical suggestions for classroom educators but that need further validation through research and testing.

The first guideline encourages educators to understand and harness the special affordances and dynamic opportunities that interactive technologies may offer student understandings of mathematics concepts and practices. The second guideline encourages teachers to identify clear mathematical learning objectives and to select technology tools to help meet these objectives. As digital tools and apps grow in functionality, availability, and entertainment value, educators need to keep primary learning goals in the forefront to prevent specific apps or the technology itself from becoming the focus of student learning. The third guideline recommends that schools and teachers create classroom cultures in which students are expected to explore their own mathematical ideas and work with peers to solve problems. A conjecture underlying this guideline is that interactive technologies can help to support mathematical thinking among students only when this type of classroom culture is in place. The fourth and fifth guidelines describe the individual and organizational supports that teachers may need to learn to use interactive technologies in ways that foster mathematical thinking among students.

Only the first guideline focuses exclusively on the features and affordances of interactive technologies. The others focus on the instructional elements that need to be in place for ambitious mathematics learning and teaching to occur. The emphasis on pedagogical, cultural, and organizational requirements for strong mathematics learning indicates a belief among meeting participants that interactive technologies by themselves cannot foster strong mathematical thinking among students. Interactive technologies are engaging and multifaceted aids in the classroom, but basic approaches toward mathematics learning and teaching need primary attention.
Appendix A.

Interactive Mobile Technologies in Early Mathematics Classrooms: ITIG Participants

Damian Bebell, Assistant Research Professor, Boston College, Boston, MA
Bronwyn Bevan, Director, Institute for Research and Learning, Exploratorium, San Francisco, CA
Pam Buffington, Managing Project Director, Education Development Center, Inc., Gardiner, ME
Amy Busey, Research Associate, Education Development Center, Inc., Waltham, MA
Kara Carpenter, Co-Founder, Teachley, New, York, NY
Lisa Coburn, Grade 1 Teacher/Team Leader Pre-K–2, Washburn School, Auburn, ME
Jere Confrey, Joseph D. Moore Distinguished University Professor, North Carolina State University, Cary, NC
Karen DeCarolis, Grade 1 Teacher, Crescent Park School, Bethel, ME
Sue Dorris, Administrator, East Auburn Community School, Auburn, ME
Bernadette Doykos, Research Associate, University of Southern Maine, Gorham, ME
Amber Eliason, Math Coach, Washburn School, Auburn, ME
Cathy Fosnot, CEO, New Perspectives on Learning, New London, CT, and Professor Emeritus of Childhood Education, City College of New York, New York, NY
Jen Helms, Researcher, Inverness Research, Denver, CO
Lisa Hogan, Technology Integrator, Freeport High School, Freeport, ME
Shannon Larsen, Assistant Professor of Elementary Mathematics and Education, University of Maine at Farmington, Farmington, ME
Linda Laughlin, Proficiency-Based Coordinator, RSU 18, Oakland, ME
Tiffany Lee, Research Scientist, University of Colorado, Boulder, School of Education, Boulder, CO
Ashley Lewis Presser, Senior Research Associate, Education Development Center, Inc., New, York, NY
Josephine Louie, Research Scientist, Education Development Center, Inc., Waltham, MA
Kelly McCormick, Associate Professor of Mathematics Education, University of Southern Maine, Gorham, ME
Catherine McCulloch, Project Director, Education Development Center, Inc., Waltham, MA
Carol Miller, Technology Coach K–6, Auburn School Department, Auburn, ME
Heather Mitchell, Researcher, Inverness Research, Lopez Island, WA
Patricia Moyer Packenham, Professor of Mathematics Education and Leadership Programs, Utah State University, Logan, UT
Mike Muir, Multiple Pathways Director, Auburn School Department, Auburn, ME
Marian Pasquale, Senior Research Scientist, Education Development Center, Inc., Waltham, MA
Laura Shaw, Principal, Washburn School, Auburn, ME
Patrick Shields, Executive Director, SRI International, Menlo Park, CA
Steve Spodaryk, Lead Technology Engineer, TERC, Cambridge, MA
Denyell Suomi, Grade 1 Teacher, Belgrade Central School, Belgrade, ME
Shawn Towle, NCSM Leader and Mathematics Teacher, Falmouth Middle School, Falmouth, ME
Phil Vahey, Director of Mathematics Learning Systems, SRI International, Menlo Park, CA
Brenda Wight, Grade 3 Teacher, Crescent Park School, Bethel, ME
Kerri Wingert, Graduate Researcher, University of Washington, Seattle, WA
Cathy Wolinsky, Instructional Technology Integrator K–4, Yarmouth Elementary School, Yarmouth, ME
Appendix B.

Resources

The resources provided in this section were shared by participants at the Interactive Mobile Technologies Inquiry Group meeting and the Interactive STEM team at EDC, and they are organized by the topics discussed under each guideline. These resources do not represent a thorough or complete literature review of the topics. Instead, they are resources the contributors find informative, thought-provoking, or potentially useful for readers who may be interested in exploring a topic further. Although some resources may be relevant for multiple topics, they are listed only once.

1. Affordances of interactive technologies

a. Capacities to represent mathematical ideas and practices


b. Capacities to provide student feedback


c. Capacities to document and share student thinking


d. Capacities to support collaborative learning


2. Mathematics learning and teaching strategies

a. Importance of setting clear learning targets


b. Mathematics learning progressions


c. Developmental appropriateness of interactive technologies


d. Allocation of time with digital and nondigital activities


e. Need for thoughtful, reflective practice


3. Classroom culture

a. Importance of promoting risk-taking and persistence in face of struggle


b. Need to build student agency and ownership over learning


c. Importance of helping students build on what they already know


d. Role of student collaboration in mathematics learning


4. Teacher supports

a. Teacher content and pedagogical knowledge in mathematics and technology


b. Role of collaboration in professional learning


c. Strategies for supporting change in teacher practice


d. Teacher and student roles in the classroom


5. Organizational arrangements

a. Instructional time for early mathematics learning and technology use


b. Access to current educational research

c. Varied teaching arrangements in early grades

d. Role of principals in mathematics learning and technology use