Integrating digital and STEM practices

Schools can leverage the ways students are already using mobile digital devices to organize and support learning activities in STEM content areas.

Shiloh and Jason, two seventh graders at a school in the Sacramento area, are making videos to capture and model linear change. Yesenia and Beatriz are interviewing their classmates about their fondness for alligators and jellyfish, and tabulating the results to test hypotheses about bias. Earl is building an interactive, three-dimensional representation of musical melodies. Andrew is creating parametric equations for the motion of his clock.

And they're doing it all on iPods.

These vignettes capture a sample of student inquiry projects and activities during a two-week pilot study exploring intersections between digital practices learners already engage in with mobile devices, and substantive aspects of mathematical practice.

Reconsidering computing in the classroom

Part of the appeal of the current generation of mobile devices – smartphones, media players and other handhelds – is their computing power, which surpasses desktop computers of the recent past. Yet as computer replacements they are problematic, with small screens, no physical keyboards, and no precision pointing devices. Their real potential, we believe, arises from the cluster of digital practices that have emerged around these devices.

As mobile devices become increasingly pervasive among youth, the gap between students with and without access to personal computers at home may soon be replaced by a new digital divide: between one set of informal ways of using those tools that are familiar, personally meaningful, and relevant to their out-of-school lives, and another set of uses in formal instruction contexts that has nothing in common with the first except hardware.

Admittedly, learners' personal forms of digital activity – texting, social networking, listening to music, watching videos, playing games – can appear quite different from and even oppositional to productive, school-based activity, and to educational uses of the same devices. But we argue for a different perspective, namely that those informal dig-

By Tobin White and Lee Martin

ital practices may provide uniquely powerful resources around which to organize innovative and engaging instructional approaches.

Many of the ways students are already using smartphones and other contemporary mobile computing devices – to take photos, capture video and audio records of events, interact and communicate with peers, consume media content, and create artifacts and personal forms of expression such as documents and photo slideshows – correspond to core aspects of disciplinary practice in STEM (Science, Technology, Engineering and Mathematics) fields.

We believe that leveraging these existing ways learners use digital devices as resources for organizing learning activities represents a particularly powerful approach to supporting student learning in STEM content areas.

Study reveals potential

A recent study conducted in four California school districts revealed some interesting results about the potential for supporting student mathematics learning with tablet computers. In randomized control trials with eighth-grade Algebra classes, students who used iPads loaded with the HMH Fuse digital textbook app performed about the same as those who used a conventional paper text.

One of the four districts, Riverside, did see significantly higher achievement among students in the experimental group. However, the success of the iPad program at that site may be explained by the fact that both students and teachers reported greater frequency of use of their devices than in the other districts.

Indeed, in an Op-Ed about the study, Educated Guess blogger John Fensterwald writes that Riverside's superintendent attributes the success of the program in his district as stemming in part from a greater willingness in their schools to freely permit learners' personal use of the iPads outside class: "Allow students to download their own applications, including music, and they'll be more prone to access math videos and use the technology for learning" (TOP-Ed, April 18, 2012).

Beneath the surface of these results lurk deeper questions about the kinds of instructional activity – technology-mediated or not – that engage learners in substantive mathematical meaning-making. The Khan Academy phenomenon of thousands of freely available online videos illustrating a wide range of topics in the K-12 math curriculum has recently invited a corresponding critique of these resources because the lecture style and the emphasis on mathematical procedures rather than concepts simply reinforces the same flawed elements of traditional instruction that turn so many students off to mathematics in offline environments.

Capitalizing on emerging media

Our own aim is not so much to challenge the use of new technology for old purposes (namely, delivering content to students in print and spoken forms) as to call attention to opportunities, often missed, to capitalize on emerging media for innovative and even transformative educational use.

Contemporary handheld and tablet computers are powerful platforms for recreating conventional instructional materials and activities in digital and mobile form, promising to replace textbooks, desktop computers, and even paper and pen with a single device. But students who have access to them are already using these devices in a much wider range of ways outside instructional settings, which we believe offer additional learning opportunities.

Modern mobile devices like smartphones, tablets and media players include tools to support several distinct forms of activity: 1. capturing and collecting information and experiences across a variety of settings, through photos, audio and video recordings, numerical and text entry, and other inputs; 2. communicating and collaborating with others via phone, text, email and social networks; 3. consuming and critiquing various forms of media including music, photos, videos, games and text documents; and 4. constructing and creating personal forms of representation and expression such as digital films, photo slideshows or archives, and blogs or other written reflections.

Each of these sets of digital practices with mobile devices has close analogs with key forms of STEM activity: collecting empirical data in a variety of forms, viewing and critically examining arguments and evidence across multiple and diverse media and representational modes, communicating STEM ideas or sharing empirical results, and producing representations to model phenomena and to examine relationships and patterns (White, Booker, Martin & Ching, 2012).

Indeed, we see in these distinct forms of digital practice the seeds of several central elements of mathematics, science and engineering practice highlighted in the Common Core Standards for Mathematical Prac-

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tice and in the Framework for K-12 Science Education (NRC, 2012).

To investigate the viability and the potential of this approach, we loaned iPod Touches to a group of 19 middle and high school students for two weeks, and met with them for an hour each day to lead them through a series of activities designed to engage them in integrating these forms of STEM disciplinary practice with aspects of personal digital activity in which most of the students already participated outside the classroom.

During the first week, students familiarized themselves with the devices and with the four categories of mobile practices outlined above. We then asked them to complete several tasks in which they were required to use those digital practices and tools to explore mathematical relationships.

For example, after one session, the students were given an assignment to use their iPods to record a short video of some observable phenomenon varying linearly over time (capturing and collecting data). Working in small groups the next day in class, they exchanged video across devices using a photo sharing app (communicating and collaborating), used a spreadsheet app to enter time-sequenced measurements (the position of an object or the volume of a liquid) as they replayed their video, plotted the resulting ordered pairs of values and created a linear model from the data in a graphing app (constructing and creating representations), and examined the resulting displays to evaluate the appropriateness of the model to represent the phenomenon (consuming and critiquing media).

In the second week, small groups identified a topic of interest, and then set about conducting empirical, mathematical investigations in which they again deployed mobile tools and practices in each of the four categories in our framework. Groups collected data (surveying peers and digitally recording responses, seeking information online), shared interim results with group members, created tabular and graphical representations of data, and presented findings to the class.

As they participated in these activities, students were engaged in developing proficiency with several important aspects of STEM practice highlighted in the Common Core and NRC standards. For example, they examined correspondences between graphical, tabular and symbolic representations (CCSMP No. 1), interpreted and evaluated mathematical models of real-world situations (CCSMP No. 4, NRC No. 2), planned and selected appropriate technological tools (represented here by a suite of available iPod apps) for various stages of an investigation (CCSMP No. 5, NRC No. 3), analyzed and interpreted data (NRC No. 4) and communicated findings (NRC No. 8).

The path we advocate here is to leverage students' existing uses of mobile devices — what we call their informal digital practices — as entry points into STEM disciplinary practices.

We certainly saw some evidence of students using their devices for non-mathematical ends during class time, and some students were reflective about the temptation to wander off task into games or social media. As one student, Earl, told us, he needed to do a lot of "self-regulating." Yet we also heard students describe the opposite pattern, where their mobile device turned idle moments into opportunities for academic work. Even on campus, students noted that computers for student use were often not available when needed. Earl also told us that it was "a lot easier to have the [iPod] Touch ... instead of [having to] wander over to a computer and hope that it's open, and that not very many people have messed with it, and then just wait for the log in to go through. Just having the device right there and you're just like, OK."

Novel and exciting ways of doing math

At the end of the pilot study, students completed an anonymous survey and an in-person interview asking them to reflect upon their experiences. Survey results showed that all students wanted to do similar activities in the future and would recommend the activities to a friend, and 93 percent said they learned new ways to do math from the activities.

Interviews highlighted that many students found creating graphs on the mobile devices to be novel and exciting. Several students said the experience shifted their view of themselves as math students. For example, one said, "I used to think [math] was too hard, and like, I said, 'I don't like it.' But what we just did, over the last two weeks, it's like 'Oh, OK, that's cool. Maybe we should do that in class.'"

Others said that their experience, especially with graphing data, made it easier to imagine themselves in a career that involved analyzing and graphing data.

Educators face a choice

The mobile revolution is well under way outside of school, both in the workplace and in people's everyday lives. Educators face a choice. One path is to focus on the potential downsides of mobiles, such as the danger of taking students' attention away from academic tasks in favor of games, media and social networking. Given this view, educators are likely to resist the penetration of mobile devices into schools and institute rules to regulate their presence and use in the classroom.

A second path is to accept the presence of mobiles and try to find ways to integrate them into existing classroom practices. In this model, mobiles might serve as calculators, calendars with homework reminders, browsers for information online, or as clickers in a classroom response system, depending on the classroom and the needs of the teacher.

Student skills as digital practitioners

A third path, as we advocate here, is to leverage students' existing uses of mobiles – what we call their informal digital practices – as entry points into STEM disciplinary practices. Instead of focusing solely on the potential utility of mobiles as convenient and potentially powerful tools, this approach instead focuses on the students' skills and knowledge as digital practitioners.

Capitalizing on students' informal digital practices provides an avenue for doing more than simply providing an out-of-school relevant "hook" to try to motivate students' interest on a problem or project. We believe it provides easier avenues for students to bring their own interests and identities into the classroom context, where they can connect to STEM practices and pathways. In doing so, we believe mobiles can help teachers move classroom work beyond the too-common focus on algorithms, facts and procedures, to also embrace mathematical practices of modeling, testing, iterating, communicating and critiquing. ■

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Lee Martin, assistant professor of education at UC Davis, studies people's efforts to enhance their own learning environments, with a particular focus on mathematical thinking and learning. In everyday settings, he looks at the varied ways in which people assemble social, material and intellectual resources for problem solving and learning. In school settings, he looks to find ways in which schools might better prepare students to be more resourceful and flexible in fostering their own learning.