Implementing Large-Scale Mobile Device Initiatives in Schools and Institutions

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Abstract This chapter discusses factors to drive the explosive growth of mobile devices in Science, Technology, Engineering, Arts, and Mathematics (STEAM). Drawing upon these factors, the chapter examines the innovations of mobile devices adopted in the STEAM classroom and barriers experienced by educators in the process of mobile technology integration. Built on the innovations and barriers of the use of mobile devices, the chapter continues to discuss what essential conditions are needed to ensure successful implementation of large-scale mobile device initiatives in STEAM. These factors, innovations, barriers, and conditions also position academic leaders and educators to rethink domain-related curriculum in STEAM and harness increasingly ubiquitous mobile technology in order to meet the needs of the 21st century.

Keywords Mobile devices · Mobile learning · Large-scale initiatives · Bring Your Own Device (BYOD) · Technology trends

Introduction—Mobile Device Trends in Schools and Institutions

The recent evolution of handheld mobile devices and wireless technology has led to large-scale implementation of mobile devices, such as tablets and smartphones, in educational settings. Anderson University in South Carolina launched The Mobile Learning Initiative, providing iPads to all biology students with apps for in-class and collaborative research projects (Anderson University, 2014). Jackson State University (JSU) provided iPads to all full-time freshmen, enabling them to access eBooks and dozens of apps that allow them to take notes, collaborate on content, communicate with instructors and peers, tap into math references, learn a foreign language, listen to thousands of audiobooks, and much more (Jackson State University News Room, 2013). Similarly, the Jeannine Rainbolt College of Education

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(JRCoE) at the University of Oklahoma provided iPads to all its full-time undergraduate students. The goal is not just to transform students' learning experiences, but also to prepare pre-service teachers to incorporate technology in their future classrooms, and to cultivate their long-term use of tablets as professional educators (JRCoE, 2013). K-12 schools are not left behind. After a brief pause and reflection, the Miami-Dade County Public School District (M-DCPS) resumed their plan to give digital devices to all 354,000 students. This initiative is one of the largest one-to-one digital computing initiatives in the country (Blazer, 2014).

There are three distinct trends that have been driving the exponential adoption of mobile devices in educational settings during the 2000s. First, unlike the late 1980s and 1990s when portable devices were primarily laptops and notebooks, the implementation of portable devices in the millennium is focusing more on smaller, handheld devices such as tablets and smartphones (Zaranis, Kalogiannakis, & Papadakis, 2013). For this reason, another trend in the 2000s is the increasing adoption of mobile learning to enhance students' experience. Researchers have indicated that mobile learning, through the use of tablets and smartphones, presents new opportunities for learning and strengthens the learning experience in ways other devices simply cannot achieve (Lam & Duan, 2012; Zaranis et al., 2013). In other words, mobile learning takes into account the mobility of technology, students, and learning (Sharples, Taylor, & Vavoula, 2007). The third trend, it follows, is that more and more schools and institutions are launching large-scale mobile device initiatives and taking a systematic approach to embrace the advantages of mobile learning (The Technology Outlook for STEM + Education 2013–2018 Report, 2013; UNESCO, 2012). The systematic approach is crucial to ensure that stakeholders such as leaders, educators, students, technicians, vendors communicate and collaborate effectively (Blazer, 2014; Herold, 2014; The Technology Outlook for STEM + Education 2013–2018 Report, 2013).

As a result of these trends, some unaddressed questions naturally come to our attention. What drives the explosive growth of mobile devices in educational settings? What happens when mobile devices are introduced and integrated in the STEAM classroom? What infrastructure should be in place to ensure a large-scale mobile device initiative succeeds and scales up? The following sections address these questions in the context of how mobile devices are implemented and administered in Science, Technology, Engineering, Art, and Math (STEAM). It will review emerging empirical studies on various aspects of research on mobile learning in STEAM education and discuss essential conditions for successful mobile device initiatives in STEAM.

Factors Influencing the Growth of Mobile Device Usage in Educational Settings

What drives the explosive growth of mobile devices in STEAM? This section will summarize three organizing factors identified in the literature regarding the mobility of technology, students, and learning.

The Mobility of Technology

The mobile market consisted of more than 6.8 billion users by 2013, and the market continues to grow (MobiThinking, 2014). A 2014 survey showed that nearly 160 million people in the U.S. owned smartphones, which is 66.8% of the total phone market penetration in the U.S. (ComScore Report, 2014). In addition to smartphones, over 70 million of 285 million tablet owners worldwide at the end of 2013 were in the U.S. (TabTimes, 2013). The widespread use of smartphones and tablets has pushed developers to further explore ways to optimize the hardware and software inside cell phones and tablets. The goal is to make mobile devices more capable, user interfaces more natural and apps more educationally friendly (Matthews, 2011; The Technology Outlook for STEM+Education 2013–2018 Report, 2013). With this understanding, a factor to drive the explosive growth of mobile devices in STEAM is the rapid development in mobile technologies that provide new possibilities for STEAM educators and students to accomplish what they otherwise could not (O'Shea, Gabriel, & Prabhu, 2010; Vogel, Spikol, Jurti, & Milrad, 2010).

A review of literature identified three major mobile advancements that enable augmented teaching and learning experience in STEAM. The first mobile advancement involves the concept of cloud computing. Cloud computing has five essential characteristics: (1) On-demand self-service, which means users can obtain computing capabilities automatically without requiring human interaction and assistance; (2) Broad network access, which enables the provision of processing, storage, remote networks, and other computing resources in mobile phones, tablets, laptops, and workstations; (3) Resource pooling, where computing resources are dynamically assigned and reassigned according to user demand; (4) Rapid elasticity, which allows hardware and software capabilities to be elastically provided and released in response to user demands; (5). Measured service, which means users and providers of the services can both monitor and control resource usage to ensure transparency of resource usage (Koutsopoulos & Kotsanis, 2014). Empowered by cloud computing capabilities, the hardware and software capabilities in mobile devices have unveiled a new era in STEAM.

In conjunction, the second advancement is the hardware capabilities in a variety of mobile platforms, which include, but are not limited to, smart phones, tablets, pocket PCs, personal audio players, personal digital assistants, e-readers, and Global Positioning Systems (GPS). The hardware in these mobile platforms usually support WiFi networking which allows the mobile device to connect to the Internet. They also support Bluetooth networking to support and increase the use of headphones, microphones, keyboards, and other peripheral devices (Koutsopoulous & Kotsanis, 2014; Minaie, Sanati-Mehrizy, Sanati-Mehrizy, & Sanati-Mehrizy, 2011; Murray & Olcese, 2011). Additionally, these platforms have hardware systems that integrate the capabilities of GPS such as depicting a map of stars and planet that are either above the horizon or below, day or night (Murray & Olcese, 2011). Moreover, a majority of tablets have a touch screen interface that not only allows various gestures such as pinch, flick, stretch, and rotate, but also allows multi-touch display. As such, a piano student, for instance, can pinch the screen to the size of his or her wish, handle more than one touch simultaneously, play multiple keys, and hear multiple notes (Murray & Olcese, 2011).

Arguably, researchers indicated that the hardware capabilities in various mobile platforms have reshaped the ways in which information is created, accessed, and disseminated in STEAM (Avraamidou, 2008; Cantrell & Knudson, 2006; STEM Education Coalition, 2014; UNESCO, 2012). For example, students can work on real-world scientific questions and solutions individually and collaboratively by using various digitally-mediated tools, such as podcasting, remote monitoring, digital recording, digital storytelling board, desktop sharing, and videoconferencing. Researchers pointed out that while students can assess these cloud-based computing tools via their desktop computers as well, mobile devices allow students to leverage the ease of access to information related to scientific questions and observations at their fingertips (Chew-Hung et al., 2012; Evagorou, 2008; Peffer, Bodzin, & Smith, 2013).

To couple with the hardware specifications in various mobile platforms, the third mobile advancement is the software applications used by mobile devices. After all, what makes a difference in how mobile devices are adopted is what applications are developed to take the advantages of the hardware. The mobile apps in Apple and Android, two of the most popular mobile operating systems, have skyrocketed during the past few years. By July 2014, more than 1.3 million apps including 10,000 education apps were created for the Android hardware, and more than 1.2 million apps including 8000 education apps were on the Apple hardware (AppBrain, 2014; iPad in Education, 2014a; The Statistics Portal, 2014). Researchers pointed out that "we are in the era of the mobile platform now, and apps is reigning as king" (Norris & Soloway, 2011, p. 5).

These educational apps cover a wide range of subjects, accommodate different learning styles, and are ambitious to change the landscape of education. For instance, the iTunes U app on the Apple platform can allow educators of all levels to create their courses featuring audio, video, books, and other content. Students can access their assignments, materials, study notes, and discussions all together in iTunes U. This app touts the ability to keep students prepared for class and engaged in learning for free and at their fingertips (iPad in Education, 2014b). Some apps such as Dropbox and Box connect to web-based services and enable efficient file sharing and archiving (Murray & Olcese, 2011). Some apps support students organizing their calendar, worksheets, homework, learning notes, tests, and projects (Novello, 2012). In the context of STEAM, a variety of apps can be leveraged to enhance teaching and learning. Some apps help STEM teachers deliver digital content such as lectures, online multimedia materials, and reference materials to students (White & Martin, 2012). Some apps allow both STEAM teachers and students to create content such as voice recordings, video and images, photo slideshows, and concept map (White & Martin, 2012). Additionally, some other apps introduce STEAM concepts, enable students to use interactive rubrics to receive immediate feedback on quizzes in preschool classrooms (Aronin & Floyd, 2013; Novello, 2012).

The Mobility of Students

Along with the mobility of technology discussed above is the second factor to drive the explosive growth of mobile devices —the mobility of students. Students today desire to move freely and easily and still be productive anywhere and anytime (Aronin & Floyd, 2013; Avraamindou, 2008; El-Hussein & Cronje, 2010; O'Shea et al., 2010). In other words, students do not want to "sit in a small space for 5 h a day while a teacher talks about the past and present" (Wiles, 2007, p. 2). Instead, they increasingly desire to access, create, and share information wherever and whenever they want (Sharples et al., 2007; The Technology Outlook for STEM + Education 2013-2018 Report (2013). For this reason, mobile devices with powerful hardware and software capabilities in cloud computing, as discussed in the previous section, meet students' desire of mobility.

Although the desktop computer still plays an important role in the classroom and student learning, its use drops every year compared with that of mobile devices (Norris & Soloway, 2011). The first reason is that desktop computing is place-bound for students while mobile devices are wireless and portable (Chew-Hung et al., 2012; El-Hussein & Cronje, 2010; Evagorou, 2008). The wireless and portable functionalities allow users to interact and collaborate more freely and easily while on the move (Chew-Hung et al., 2012; El-Hussein & Cronje, 2010; Evagorou, 2008). The second reason is that the use of mobile devices represents a shift from a teacher-driven approach to a student-centered learning environment where students are encouraged to interact and collaborate when they are on move (Koutsopoulos & Kotsanis, 2014; Serio, Ibáňez, & Kloos, 2013). Specifically, in a student-centered learning environment, the availability of mobile devices to students is inevitable because students nowadays "do more than reproduce knowledge; they question and challenge the ideas of others and forward their own opinions and ideas" (Koutsopoulos & Kotsanis, 2014, p. 50). Such an observation aligned with the results of a recent study of 2350 K-12 students who valued a student-centered learning environment with mobile devices. According to the survey, 92 % of the surveyed students in elementary, middle, and high school in the U.S. believed that mobile devices will change the way they learn in the future and make learning more fun. Moreover, 69 % of them would like to see more mobile device integration in their classrooms (Booker, 2013). "It is inevitable that all computing will be mobile" (Norris & Soloway, 2011, p. 5).

To scale up the use of mobile devices in the classroom, some K-12 schools which usually prefer to provide mobile devices to students now allow their students to bring their own devices to the classrooms including tablets, phones, and laptops (CISCO, 2012; George, 2014). Bring Your Own Device (BYOD) allows students access to the same mobile devices at school and at home without switching among devices, thus making students work with technology with which they are already comfortable and familiar (CISCO, 2012; Horizon Project, 2013). Researchers and educators stated that Bring Your Own Device (BYOD) is a great approach to engage students in that the devices are integral to the world in which students live, therefore, BYOD will make learning part of their lives and enable a personalized learning experience (El-Hussein & Cronje, 2010; George, 2014; Horizon Project, 2013; Walling, 2012). Instead of banning BYOD, researchers argued that schools should teach students how to use their own devices properly (CISCO, 2012; DeWitt, 2012).

In the context of STEAM, the mobility of students ensures that learning activities turn quickly from concept to reality. For example, STEAM freshmen at Jackson State University enjoyed carrying their iPads provided by the university to do graphing calculation and access math reference formulas in class and outside of the classroom (Jackson State University, 2013). Students at Instituto Technologicoy de Estudios Superiores de Monterrey were engaged in a Mobile Intelligent Laboratory, in which students collaborated on the move in a physics experiment. In the same fashion, art students adopted a BYOD approach to create and leverage a mobile blogging site to bridge meaning making across school and various art museum settings (Pierroux, Krange, & Sem, 2011).

The Mobility of Learning

The third factor to drive the explosive growth of mobile devices in STEAM is that online learning has become mainstream and is optimized for mobile learning. A survey supported by the Sloan Foundation found that senior executives in higher education—presidents, provosts, deans, campus leaders—increasingly considered online learning as a strategic element in policy making. The survey also reported that 66 % of the senior academic officers from 2500 colleges and universities agreed that online learning was a critical element in their institutional strategic goals (Allen & Seaman, 2013). As a result, schools and institutions are adding new online courses and programs, adopting apps into their curriculum, and modifying websites, educational materials, resources, and tools to optimize learning for mobile devices (The Technology Outlook for STEM+Education 2013–2018 Report, 2012). For instance, Brown University launched a free online engineering course to teach high school students about the merits and challenges of the field (The New York Times, 2013). Florence-Darlington Technical College created the online physics course "Power Up: High Tech Online" to train the next generation of nuclear engineers by virtually connecting students with nuclear professionals (The Huffington Post, 2013).

Mobile learning is at the intersection of online learning and mobile computing (El-Hussein & Cronje, 2010). Schools and universities are involved in pioneering experiments for transmitting all instructional online materials to students by means of mobile devices (El-Hussein & Cronje, 2010; Walker, 2007). One noticeable trend is that schools and universities are employing mobile apps in their learning management systems (LMS). Schoology, a LMS adopted by K-12 teachers, recently released a mobile app that helps teachers streamline student submissions and the grading workflow with a simple gesture: swiping left or right in a mobile device (STEMblog, 2014). Blackboard, the most widely adopted LMS in higher education in the U.S., offers a mobile platform to allow students access to all content and assignments virtually anywhere with any types of mobile devices including smartphones (Blackboard Mobile Learn, 2014). Desire2Learn, another big player of LMS in higher education, touts to let students take charge of their learning experience when they can easily work with course materials, cloud drives, and mobiles apps all in one place—at the students' fingertips (Desire@Learn Binder, 2014). Together with the mobility of technology and students, mobile LMS save students' and faculty's valuable time spent in going through the regular LMS processes in the desktop computing, which can now be done while they are on the move (University of Central Oklahoma, 2014).

All things considered, the three key factors—the mobility of technology, students, and learning—drive the widespread growth of mobile devices in schools, universities and the STEAM sector. The following section discusses what happens when mobile applications are integrated into the curriculum.

Mobile Applications and Technology Integration Barriers in STEAM

As discussed in the previous section, advanced mobile communication, hardware, and software capabilities have enabled augmented teaching and learning experiences in STEAM that otherwise could not be accomplished. Educators now are challenged to develop innovative ways to integrate mobile devices into their curricula. What happens when mobile devices are introduced and integrated in the STEAM classroom?

Mobile Applications in the STEAM Classroom

The use of mobile devices is playing an increasingly pivotal role in transforming the landscape of teaching and learning in STEAM (Ahmed & Parsons, 2012; Lutz, Schäfer, & Diehl, 2012; STEM Education Coalition, 2014; UNESCO, 2012). Research in STEAM has explored many aspects of integrating mobile devices into curricula to support and augment a variety of learning activities.

In science settings, mobile devices were used in a variety of contexts and for different purposes. Some educators used mobile devices to promote inquiry-based science learning (Ahmed & Parsons, 2012; Vogel et al., 2010). In an ecology course, mobile devices were used to support flexible ecology learning contexts in various locations across school and home contexts (Luckin et al., 2005). Additionally, educators used mobile devices to support student learning in informal science settings as a continuum from formal science settings (Scanlon, Jones, & Waycott, 2005). Mobile devices were also used to connect to a local wireless network so as to document and share information quickly during professional field trips (Cantrell & Knudson, 2006).

Mobile computing is becoming widely integrated in the undergraduate and graduate curricula within computer science and computer engineering settings. A survey of 33 universities, from Carnegie Melon University to Utah State University, indicated that the majority of these surveyed universities were offering graduate courses on mobile computing (Minaie et al., 2011). Meanwhile, many programs in these surveyed universities had lined up to change their curricula to offer mobile computing courses for their undergraduate students, too. As such, computer science educators are implementing mobile devices to serve a variety of purposes. One educator integrated handheld devices into a programming course and had students deploy mobile applications to support lab-intensive courses (Mahmoud, 2008). Similarly, some educators used mobile devices to create collaborative learning activities during lecture to scale up lecture-based courses. A majority of the students in the study found the redesigned courses with mobile devices more motivating and engaging (Simon, Anderson, Hoyer, & Hu 2004).

In engineering classrooms, team-based learning is a key aspect of any student's academic success (Lutz et al., 2012). For this reason, the use of mobile devices focused on creating collaborative learning environments for students. In higher education, students used mobile apps to create remote labs so that they could collaborate and help each other in those rote labs (Barcia-Zubia, López-de-Ipiña, & Orduña, 2010). Another study reported that engineering students used mobile devices consistently to build a collaborative environment in the classroom, in which teamwork is a required component in engineering education (Lutz et al., 2012). In K-12 environments, elementary school girls used mobile devices in a *Simple Machine in Your Life* project to collaboratively learn about the simple machines in their surroundings. Moreover, elementary students in the *GreenHat* project used a GPS-enabled Smartphone to explore the natural environment through expert's perspectives in their group assignments (Ryokai, Agogino, & Oehlberg, 2012).

In mathematics settings, the use of mobile devices usually focuses on helping students solve authentic math questions. A study showed that middle school students worked as mathematicians by carrying out authentic math activities using mobile phones collaboratively. The study filled a literature gap that few research studies had examined middle school students' building of mathematical knowledge using mobile phones (Daher, 2010). Educators also used mobile devices to teach realistic mathematics to kindergarten students (Zaranis et al., 2013). Moreover, educators developed an application to support families in real-life situations where problem solving involved mathematics (Alexander et al., 2010).

In art settings, mobile devices are also widely used in order to design authentic opportunities for learning where students "do" arts, therefore, motivating heretofore unmotivated students. First, augmented reality (AR), which integrated 3-D virtual objects into a 3-D real environment in real time, is a great way to motivate students by connecting to real or simulated 3-D environments (O'Shea et al., 2010; Serio et al., 2013). In an art course, students used an AR system and incorporated location-aware mobile technologies to trigger digital characters, objects, and events on Asian arts. Eventually, the mobile technologies helped these art students create, implement, and evaluate their augmented reality experience for the San Diego Museum of Arts (O'Shea et al., 2010). Similarly, an augmented reality system was deployed in mobile devices to motivate middle school students learning in a visual art course. Results found that students' attention and motivation in a learning environment based on augmented-reality were much better than those obtained in a PowerPoint-slides-based learning environment (Serio et al., 2013). Moreover, AR was also integrated into a mobile guide system in a painting course to teach students painting appreciation (Change et al., 2014). Second, in addition to AR, mobile devices were also used creatively to enhance traditional ways of learning arts. One study showed that educators used digital media and tools on tablets to prepare all arts majors to enhance traditional drawing and design media (Moore College, 2014). In the same fashion, art students created and leveraged a mobile blogging site with their mobile devices to bridge meaning making across school and various art museum settings (Pierroux et al., 2011).

The examination of the above-mentioned studies indicated various ways of using mobile devices to support innovative learning environments in domain-related curriculum in STEAM. Now powered by mobile devices, do STEAM educators transition well from traditional instruction to mobile-device-enhanced instruction? What barriers have they experienced in the process of mobile technology integration in their curricula?

Barriers to Effective Mobile Technology Integration in STEAM Curricula

Compared with the exciting capabilities of mobile technologies, less exciting news is that many STEAM educators also reported barriers to effectively integrating mobile devices into their curricula. Some barriers of mobile technologies were related to what Ertmer (1999, 2005) called first-order or external barriers, such as access to technology, time, training of technology use, and support (Bannon, Martin, & Nunes-Bufford, 2012; Hechter & Vermette, 2013). National data consistently showed increasing improvement in the access of mobile devices, bandwidth, technical support, and training on the mechanical use of mobile devices in the K-12 and university classrooms (O'Shea et al., 2010; The Technology Outlook for STEM+Education 2013–2018 Report, 2013; Vogel et al., 2010). In particular, the Federal Communications Commission made available more than $ 2 billion in 2014 and $ 1 billion annually afterwards to significantly expand Wi-Fi networks to all schools and libraries (Federal Communications Commission, 2014).

Another barrier to the use of mobile devices is related to the digital divide. The notion of digital divide is that not everyone has access to technology and Internet. The unbalanced access to technology and Internet could further divide a growing gap between the underprivileged members of society and the wealthy, middle-class people in terms of their access to, use of, or knowledge of information and communication technologies (Dewan & Riggins, 2005; Warschauer, 2004). The digital divide could pose new concerns in the age of social networking and mobile devices as well (Bauerlein, 2011). A few schools experienced the concern of digital divide in their mobile device initiatives when some economically disadvantaged K-12 students and parents complained not having Wi-Fi at home when mobile devices were allowed to bring home (Herold, 2014; Iasevoli, 2013). Although literature is lacking to examine how digital divide could affect mobile teaching and learning in the STEAM settings, it could shed lights to STEAM leaders and educators during planning.

Beyond access, bandwidth, technical support, and the digital device—the first order of effective mobile technology integration, the literature documented a prevalent barrier to hinder mobile technology integration in STEAM—the second-order or internal barriers of effective pedagogy of technology integration (Ertmer, 1999, 2005). Studies reported that STEAM teachers experienced great barriers in using effective pedagogy to integrate mobile technology into their classrooms. In a recent survey of 430 in-service science educators, 80% of them indicated that various technologies, including mobile devices are available to them. However, about one quarter of respondents stated that they did not receive effective pedagogical training of technology integration (Hechter & Vermette, 2013). In a survey of urban school mathematics teachers, researchers also found that while mobile technologies were widely accessible to students and teachers, a decline of the use and integration of computer technology, including mobile devices, was apparent among the surveyed mathematics teachers (Wachira & Keengwe, 2011).

Clearly, when STEAM educators passed the initial phase of the mechanical use of mobile devices, they experienced more barriers in pedagogically integrating mobile technologies. In other words, it is critical for STEAM educators to understand that mobile devices are not just about the availability of tools and apps, but more about a new way of thinking and teaching (The Technology Outlook for STEM+Education 2013–2018 Report, 2013; Windschitl, 2009). In particular, the effective pedagogy of technology integration means "incorporating technology and technology practices into all aspects of teaching and learning, specifically, incorporating appropriate technology in objectives, lessons, and assessment of learning outcomes" (Wachira & Keengwe, 2011, p. 17). Researchers identified that teachers' fundamental beliefs about teacher-student roles, curricular emphases, and assessment practices had significant impact on their effective technology integration (Ertmer, 1999, 2005; Hew & Brush, 2007). In relation to technology integration in science, it is suggested to use constructivist pedagogies that encourage hands-on applications with science-based technologies and that allow students to interact with their peers (Harris, 2005). As for mobile technology integration in mathematics, it is recommended focusing on student-centered active learning strategies and also aligning appropriate mobile applications with learning activities (Bannon et al., 2012).

A question naturally arises whether STEAM educators receive necessary professional training on mobile technology integration into their curricula. Unfortunately, despite the widespread recognition of the importance of mobile learning in STEAM, many STEAM educators have not had training or professional development opportunities equipping them to effectively adopt best pedagogies of mobile technology (Meyer, 2013). Researchers called for systematic teacher preparation and professional development for STEAM educators (Bannon et al., 2012; Hechter & Vermette, 2013; Meyer, 2013; The Technology Outlook for STEM+Education 2013–2018 Report, 2013; Windschitl, 2009). Arguably, it is critical for schools and institutions to provide initial technical support along with ongoing professional development opportunities to address STEAM educators' external and internal barriers. Such support and opportunities are part of the essential conditions for successful mobile device initiatives that will be discussed in the following section.

Essential Conditions for Successful Mobile Device Initiatives in STEAM

What infrastructure should be in place to ensure a large-scale mobile device initiative to succeed and scale up? The following section answers this question in the context of STEAM.

Visionary Leadership and Commitment

As in any large-scale initiative, visionary leadership and commitment are central to spearheading innovation and change in STEAM (Abdul-Alim, 2012). Visionary leaders should position mobile device initiatives as part of the overall institutional goals and efforts to get broader support from educators, students, and departments (MindShift, 2012). Anderson University (AU) launched their Mobile Learning Initiative in 2011. The initiative particularly enabled biology and art students to benefit huge gains in student understanding of materials. The leadership of the University touts their commitment to be a pioneer of mobile technology in STEAM and overall undergraduate education (Anderson University, 2014). Similarly, the Moore iPad Initiative at the Moore College of Art was strongly supported by its top administration. Their Academic Dean, Dona Lantz stated that: "Faculty at Moore are committed to educating students for contemporary careers in art and design. The iPad is a pivotal learning tool in the new Foundation curriculum where the integration of digital media and tools are taught and used in tandem with traditional drawing and design media" (The Moore iPad Initiative, 2014, p. 1).

In the same fashion, some institutions have established a center, office, or committee at the state, or institutional level to support the use of mobile devices in STEAM education. The Carnegie Science Center, which is one of the four Carnegie Museums of Pittsburgh, partnered with the Army National Guard's Mobile Learning Center Programs to promote a cutting-edge mobile teaching and learning lab (Hohenbrink, 2011). The State of North Carolina has a STEM Center that serves as a catalyst for innovation and change. They collaborated with institutions and schools to provide educational services, grants for mobile device initiatives, and professional development opportunities on mobile technology (SMT, 2014).

In contrast, weak leadership can sink a well-intentioned large-scale mobile initiative. In particular, weak leaders would see mobile device initiatives as a technology project, rush to roll out the mobile devices, and not communicate or collaborate effectively across different departments (Roscorla, 2014). A case in point is Los Angeles Unified School District's (LAUSD) iPad initiative in 2013. As the nation's second-largest school district, LAUSD planned to distribute iPads to all of its 651,000 students by the end of 2014. Soon after, the LAUSD had to dramatically scale back its initiative. One of the biggest complaints was that district leaders had rushed the deployment of the mobile devices without planning strategically, setting realistic timelines, and getting buy-in from educators (Herold, 2014).

Clearly, strategic leadership is critical to communicate and harmonize the coordination of access of mobile devices, bandwidth, technical support, the digital divide, and professional development, among other issues (Herold, 2014; O'Shea et al., 2010; Roscorla, 2014; The Technology Outlook for STEM + Education 2013–2018 Report, 2013; Vogel et al., 2010). Putting strong leadership in the context of mobile device initiatives in STEAM, it is clear that strong leaders draw capable people to cultivate a unified vision across the board so that the vision of large-scale mobile device initiatives can be implemented as a cautionary tale (MindShift, 2012).

Strategic Education Goals

Mobile device initiatives should work in harmony with strategic educational goals such as making learning mobile, supporting different learning needs, leveraging advanced technologies and online resources, and reaching students who would not otherwise have the opportunity to participate (Kukulska-Hulme & Sharpe, 2007). These educational goals should be aligned with curriculum redesign, technology integration, and assessment when mobile device initiatives are mapped out. It is critical that people involved in implementing the initiatives have a clear understanding of the goals, intended outcomes, and risks (UNESCO, 2012). A case in point: the Miami-Dade County Public Schools (M-DCPS) in Florida paused their one-to-one computing initiative to give digital devices to all of its 354,000 students. Learning from Los Angeles Unified School District's (LAUSD) mistakes, M-DCPS reviewed their educational goals and assessment plans before they resumed the initiative in 2015 (Blazer, 2014)

One mistake from LAUSD and M-DCPS's large-scale rollout of mobile devices that these initiatives were promoted as a technology initiative (Herold, 2014; Iasevoli, 2013). In fact, if that happens, educators and students may perceive the tool as a fad or passing trend. Instead, a mobile device initiative should be purposed and positioned as an educational initiative to support or transform pedagogy and curriculum (MindShift, 2012). As discussed in Section "Mobile Applications in the STEAM classroom", a large body of studies in mobile applications across STEAM-related curricula focused on leveraging mobile devices to support and augment learning activities that could not be done traditionally (Ahmed & Parsons, 2012; Lutz et al., 2012; STEM Education Coalition, 2014; UNESCO, 2012). The ultimate educational goals in these learning activities with mobile devices are to promote critical thinking, problem solving, and collaboration (Ahmed & Parsons, 2012; Barcia-Zubia et al., 2010; O'Shea et al., 2010; Zaranis et al., 2013).

Overall, any mobile device initiative should not be a stand-alone component just about the availability of tools; rather, it should be aligned with strategic educational goals and objectives. In doing so, the mobile device initiative is more likely to get broader support from educators, students, and departments (MindShift, 2012).

Educational Scalability

When mobile devices are introduced in schools and institutions on a large scale, *start small, think big* is the guiding principle many schools and institutions employ when implementing and managing their initiatives (MindShift, 2012; UNESCO, 2012). The reason is two-fold. First, the initial small-scale implementation can decrease risk tremendously, help diagnose problems quickly, and revise strategic planning accordingly (Blazer, 2014; Herold, 2014). Second, the experience gained from a small-scale mobile device project can help lay out the foundation for expansion, so that large-scale implementation across the campus can have a better chance to succeed.

A few schools and institutions have started their mobile device initiative small and scaled it up. Canby School District in Oregon began with iPod touches and iPads in just a few classrooms. On the basis of those experiences, they expanded to more classrooms in the next year (Dungca, 2011). Saddleback Valley Unified School District, Rockdale Independent School District, and Kathy Independent School District all started their “Bring Your Own Device” (BYOD) pilot programs first. They reflected on implementation and lessons learned and continued to expand their success to more classrooms (MindShift, 2012). Similarly, Anderson University started their Mobile Learning Initiatives with a few biology courses. Building on their experiences, their officials expected that nearly one third of all courses would be redesigned for mobile learning in the coming years (Anderson University, 2014).

Sufficient Professional Development

To help STEAM educators better understand the process of integrating technology into their curricula in a way that adds the most value to learning from mobile devices, it is critical to develop a comprehensive approach to engage educators in professional development opportunities. These opportunities should include not just how to use the devices, which is a common pitfall in incorporating new technology (MindShift, 2012), but also how to integrate mobile devices into STEAM teachers’ pedagogical repertoire and promote critical thinking, problem solving, and collaboration, as discussed in Section “Mobile Applications in the STEAM Classroom” (Ahmed & Parsons, 2012; Barcia-Zubia et al., 2010; O’Shea et al., 2010; Zaranis et al., 2013). In other words, transforming the role of educators by using effective mobile technology pedagogy will tailor students’ needs in their learning experience and improve student engagement and interest in STEAM subjects (Koutsopoulos

& Kotsanis, 2014; Meyer, 2013; The Technology Outlook for STEM+Education 2013–2018 Report, 2013; Windschitl, 2009).

To address the mobile technology integration issue effectively, some institutions have implemented collective and collaborative training programs. One effective strategy is to put STEAM teachers in professional learning communities (PLCs) so that they can learn, share, and support each other (Fulton & Britton, 2011; Mindshift, 2012). For instance, the UTeach Institute, launched by the University of Texas at Austin, aims to model a variety of pedagogical methods to aspiring teachers in PLCs to use mobile devices in STEM (Bolkan, 2013). With 35 participating universities across the country, the UTeach Institute trains pre-service teachers to incorporate mobile technologies into inquiry-based lessons. Additionally, a math teacher education program had pre-service teachers use iPads to facilitate collaborative and authentic professional learning experiences (Kearney & Maher, 2013).

Robust Technology Capacity

Wireless networks must now routinely host a wide range of mobile devices running bandwidth-intensive applications such as videos and music. As such, a successful mobile device initiative requires a thorough analysis of existing technological infrastructure such as wireless connectivity throughout the campus, broadband requirements, hardware and software, data storage, off-campus access, security and privacy, technical support, accepted use policies, among other infrastructural features (MindShift, 2012; Scott, 2012; UNESCO, 2012). In fact, a careful analysis of existing technological infrastructure should be the first step in ensuring that a mobile device initiative can and will support educational goals (Scott, 2012). Without robust technology capacity, it is likely that a mobile device initiative would not reach its potential technically, pedagogically, or logistically (MindShift, 2012).

Additionally, it is suggested that more wireless access points be installed across campuses, especially in high density environments, where users can carry two or three mobile devices generating significant increases in the amount of traffic (Netgear, 2014). Meanwhile, maintenance issues, such as Wi-Fi connectivity, access points, upgrades, and various application support for different operating systems and hardware, must be taken into consideration (JISC Digital Media, 2014; Netgear, 2014). It is suggested that schools and institutions start by accommodating whichever the most commonly used mobile platform and trying to reach as many devices as possible (JISC Digital Media, 2014).

Supporting Policies

To support their mobile device initiatives, many schools and institutions may need to revise their existing policies or create new policies. On the one hand, some existing policies may need to be reviewed to determine whether mobile learning disrupts or fits into traditional education approaches. Any policy that prohibits students from using portable devices in learning should be eliminated (UNESCO, 2012). For instance, some schools and institutions have changed wording from *acceptable use* to *responsible use* in their rules and guidance documents (Scott, 2012; UNESCO, 2012). The shift indicated a change in mindset. Instead of simply policing whether students' use of mobile devices, especially the use of their own devices (BYOD), is acceptable or not, the goal is to move toward making students responsible for their behavior when using their devices (CISCO, 2012; DeWitt, 2012).

On the other hand, schools and institutions may need to create new policies to guide a collection of users for various purposes. For example, new policy for mobile devices can be created to ensure that all e-mail communication about patient care and non-public matters in a smartphone or tablet is secure and confidential (Research Information Services & Computing, 2014). Another example is that more than 300 high school students at LAUSD skirted the tablets' security to surf social-networking sites during learning (Iasevoli, 2013). For this reason, a new security policy will ensure that mobile devices will not be left out of a common set of security settings as well (Microsoft, 2014; Research Information Services & Computing, 2014). Meanwhile, the process of creating new policies must be triangulated with evidence of students' learning experience and performance with mobile devices (UNESCO, 2012). In doing so, the new policies can better support initiatives in terms of scaling up or being broad enough to allow for different contexts (Scott, 2012; UNESCO, 2012).

Conclusion

In summary, this chapter discusses factors to drive explosive growth of mobile devices in STEAM. Drawing upon these factors, the chapter provides ample evidence that mobile devices have transformed how STEAM is learned and taught within and outside of the classrooms. In the meanwhile, educators also have experienced barriers in the process of mobile device integration into their curricula. Built on the innovations of the use of mobile devices in the STEAM classroom, the chapter proceeds to discuss essential conditions that ensure the successful implementation of large-scale mobile device initiatives in schools and institutions.

Building on this chapter and looking forward, more empirical studies are needed to provide evidence on the following major areas to help scale up the initial usage of mobile devices in the STEAM classroom (Ahmed & Parsons, 2012; Avraamidou, 2008; Bauerlein, 2011; Luckin et al., 2005; Lutz et al., 2012; O'Shea et al., 2010; Serio et al., 2013; STEM Education Coalition, 2014).

- Innovations and details of the processes by which students come to understand STEAM subjects through mobile devices
- Best pedagogical practices and barriers of technology integration in domain-related curriculum for STEAM educators
- Evidence of student learning gains through mobile devices

- Best practices of professional development model to support STEAM educators
- Interactions and collaborations of stakeholders and support system
- Impact of mobile devices on digital divide
- Support system and new policies necessary for large-scale mobile device initiatives

The evidence of empirical studies will help educators pedagogically, technically, and administratively respond to the increasingly ubiquitous mobile learning in order to meet the needs of the 21st century (Bolkan, 2013; Fulton & Britton, 2011; Meyer, 2013; Windschitl, 2009). Equally important is that the evidence of empirical studies will help academic leaders rethink school and institutional goals and resources in order to support STEAM-curriculum innovations on a large-scale level (Horizon Project, 2013; Lam & Duan, 2012; UNESCO, 2012; Zaranis et al., 2013).

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