Visualizing Solutions: Apps as Cognitive Stepping-Stones in the Learning Process

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Abstract: In many K-12 and higher education contexts, the use of smart mobile devices increasingly affords learning experiences that are situated, authentic and connected. While earlier reviews of mobile technology may have led to criticism of these devices as being largely for consumption, many current uses emphasize creativity and productivity, with diverse purposes ranging from blogging and social networking to near full-scale video editing, office productivity and language translation. These affordances are further made possible by the large-scale development of mobile applications (or apps). For the vast majority of mobile device users - now numbering in the billions – many of these learning experiences are informal and just-in-time, sometimes unplanned, unsanctioned by educational discourse and beyond the immediate locus of institutional control. As smart technologies become increasingly an extension of the personal, educators are faced with the question: how can we best facilitate and explicate the learning process and design relevant experiences that leverage the affordances of so many mobile devices? This paper explores how the effective use of apps enable the learning process to be visualized in ways that support meaningful and student-centered learning. The authors discuss recent developments in technology, mobile learning and multiliteracies, drawing on a range of case studies deploying mobile devices and using apps as part of learner-led inquiry processes to enable creativity, collaboration and critical thinking. Emerging from these case studies are real classroom examples, teacher-student reflections, scaffolds and working models that all speak to the importance of using apps to visualize learning and support learners at each stage of the learning process. Exploring the connections between mobile devices, media literacy and visual literacy, the paper also emphasizes the collaborative affordances of many current apps and the importance of multimodal forms of representation through gesture, voice, text, video and audio. Citing the common issues involved in deploying mobile devices in most education institutions, the authors argue the need for schools and education systems to move away from infrastructure-led developments towards more learner-led solutions.

Keywords: apps, m-learning, tablets, smartphones, inquiry

1. Introduction

Recent sales forecast data illustrate the rapid growth of mobile devices around the world (IDC, 2014). While these figures show an exponential increase in the number of smartphones and tablets sold, sales of desktop and laptop (portable) computers show little growth in the short-to-mid term and decline in the long term. Sales of mobile devices – and especially tablets – will continue to further challenge traditional forms of computation. In particular, as the number of technology devices and tools escalates, there is now a growing emphasis on the personalization of technology for the individual. Increasingly, users are able to tailor mobile devices to suit their needs through ubiquitous access to Internet connectivity and the use of personalized apps on what are, essentially, very personal computers. As more people explore mobile devices as tools for productivity, creativity, collaboration and sharing, the affordances of these devices will continue to adapt to users' needs and interests. A recent example is the development of full-featured office suites for the iPad. As an established device, the iPad now represents a whole ecosystem, having been regarded as the "first of a new class of devices that is now being used in educational settings" (Reid & Ostashewski, 2011, p. 1661). As a term, "ecosystem" implies that there is a broader architecture surrounding the device and established relationships between the software, hardware and services underpinned by common platforms, operating through the exchange of information and system resources (Messerschmitt & Szyperski, 2003). Examining the device and its ecosystem, earlier criticisms of the iPad tended to label it as a tool for "consumption" (Rodrigues, 2011), reflecting broader concerns that mobile devices represent "appliances" rather than full-featured computers (Zittrain, 2009). However, with office productivity suites like Microsoft Office, Google Docs, and iWork now available, users are choosing to employ iPads for office productivity (amongst many other uses), supplanting the need for a traditional desktop or laptop computer and, to an extent, redefining the capabilities of tablet devices. Competition from other platforms such as Microsoft's Surface Pro Tablet – with a full-featured Windows operating system – means that affordances on all tablet devices are likely to expand as a result of

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market pressure, growing user bases, competition and consumer needs, and that at least part of this expansion will involve supplanting traditional computing devices.

2. New Times, New Literacies

In their comprehensive review of the literature, Rossing, Miller, Cecil and Stamper (2012) define mobile learning (often referred to as m-learning) as "the efficient and effective use of wireless and digital devices and technologies to enhance learners' individual outcomes during participation in learning activities" (p. 2). It could be argued that this definition only begins to explain these tools, with their mobile and portable nature being key to these devices. In many contexts, mobile learning has been on the horizon for some years (Johnson, Levine, Smith, & Smythe, 2009). During this time, a number of educational jurisdictions have been exploring the use of mobile devices - especially tablets – in the classroom. In some cases, this involves the trial use of a small number of devices by interested teachers. Elsewhere, students purchase their own mobile device and bring it to the classroom in schools where the infrastructure allows the device to be used ("bring your own device," or BYOD), while other schools mandate the use of a particular device that is deployed as part of many 1-1 (one device for every one student) programs. While technology programs that scale the specific use of devices are not new, the advent of mobile hardware - with often-superior battery life, lightweight and portable - has given fresh impetus to the broader use of technology in many schooling systems. These developments have seen an increase in the number of school programs where mobile devices are deployed or brought to the classroom.

At the same time, as more mobile devices are used in classroom settings, the need to think beyond traditional print-based literacies is increasingly reflected in school curricula, teacher pedagogies and educational research. Learners now have a wider range of options for interacting with digital content, and the visual nature of many mobile apps and interfaces is playing a key role in extending the range of literacies being explored. For example, apps support newer forms of content creation such as "mashups," where learners respond to multimedia by creating new texts that include segments of images, audio and video that represent new meanings through the layering of this digital material. Most apps are internet-enabled and allow content to be shared, co-authored and published. Websites like Creative Commons encourage open engagement with visual content, providing stimulus and inspiration to learners when interacting with content and each other. Rather than the traditional keyboard and mouse interfaces – oriented around text and simple graphical user interfaces – mobile devices enable gestural and voice control, with most devices including video cameras for capturing and sharing content in real time.

While the body of research that exists in relation to largely pre-Internet visual media still holds relevance, there is a need to update current thinking on the relationship between technology, media literacies and visual literacies. For example, earlier research in visual literacy has explored the extent to which, "reality itself is mediated by visual images," including the role of the associations the viewer brings to the visual text, how they are positioned by the composer and the importance of visual intertextuality (Stephens, 1998, p. 165). At the same time, earlier discussions of visual literacy that pertain to pre-Internet text types – such as magazine images, billboard advertisements and photo scrapbooks – underscore the limitations of the composer-viewer relationship with these static, older forms of media. In these earlier visual media, viewers are often automatically positioned as passive consumers of content. Most of these forms of media are largely or solely "one-way" in terms of content being conveyed from the composer to the responder on technology tools such as the television and radio. The viewer's "response" to visual texts within this paradigm often involves analytical and meta-analytical discourses, but not always learner engagement with the tools of production available to the composer of the original text. However, with recent technologies, learners are part of the same paradigm, having access to low cost devices capable of near-professional production.

When thinking about this paradigm shift in terms of literacies, some have argued that new media literacies are much more about discourse-based actions than skills. Lankshear and Knobel (2006) define literacies within the new media paradigm as "socially recognized ways of generating, communicating and negotiating meaningful content through the medium of encoded texts within contexts of participation in Discourses (or, as members of Discourses)" (p. 64). Citing the impact of Web 2.0 with a growing number of web applications that support creativity and sharing, they argue that the digital age encourages literacies as forms of doing and being. When learners engage with these forms, they extend the range and nature of literacies that exist. In this context, learners play a vital role in mediating an increasingly visual reality through the use of technology tools that

enable newer interfaces. As Mallia (2013) states with respect to the important relationship between visual literacy and the use of technology tools:

> *Although visual perception seems to precede any textual explanation, the combination of images, media and new technologies will require students to be multiliterate. This new literacy will fuse visual literacy with innovative forms of technology and digital communications. As we are in the beginning of a new millennium, it is evident multimedia visual literacy is essential to our culture, wherein visual technology is connected to the communication needs of the current generation (p. 369).*

In summary, mobile devices are encouraging a much wider range of literacies as forms of doing and being in a digital age. Rather than being the passive consumers of the pre-Internet age, learners are now able to employ the tools of professional composition to create, co-author and publish visual texts to reflect their world. As highly personal, portable connected, mobile devices play an integral role in shaping these emerging forms of literacy.

3. Schools and Smart Mobile Devices – Exploring the Evidence

Given the possibilities, it is important to consider the evidence supporting the use of smart mobile devices in schools. Some researchers have tended to raise more concerns and questions than clearly identified positive outcomes. For example, in a study of high school and primary students' use of iPods and iPads in a school where these devices were deployed in two phases, Crichton, Pegler and White (2012) found that when given the choice between using tablets and laptops, students only preferred tablets "for a variety of commonplace tasks," while preferring laptops for "for searching the Internet, creating media, and checking email." This study also found that in relation to iPad use in the classroom, "high school students and teachers were more critical [than primary students], as both appeared to struggle to find educational uses for the devices" (p. 23). In another comparative study, Culén and Gasparini (2011) found similar resistance among both high school and tertiary students, reflecting the perceptions of the iPad as not an effective "platform for work purposes" (p. 200). Drawing attention to the considerable differences between iPad affordances and those of traditional (and still common) computer labs, Khaddage and Zeidan (2012) question whether most higher education institutions are ready for tablet devices as learning tools.

However, other findings for a range of education contexts have been more encouraging. For example, in a study of 1-to-1 iPad deployment in one high school, Foote (2012) found that the deployment itself fostered "an exploratory climate on campus—as teachers, students, and administrators learn at the same time how to use the iPad and what it will mean for their teaching" (p. 18). Similarly, an early study in tablet use in school with a Cooperative Learning environment found that the devices were especially useful in fostering productive collaborative learning while improving interactions between peers and instructors, "where students are engaged in higher level thinking activities such as problem solving and discussion of complex ideas" (Shuler, Hutchins, & LaShell, 2010, p. 11). Likewise, a higher education study of over two hundred undergraduate students closely measured perceptions of the iPad when used as "a *supplemental* learning tool in the classroom," finding perceptions to be, on the whole, quite positive and noting that the device aided problem solving, connection of ideas and improved participation and interaction (Rossing et al., 2012, p. 1, our emphasis).

These strengths and weaknesses flagged in recent research reflect underlying concerns in many education institutions that smart mobile devices may not have, up until very recently, represented viable alternatives to traditional computers. However, such concerns are often shaped by each school's collective understanding of technology learning affordances, the existing curricula and pedagogical approaches. Ensuring that educators incorporate meaningful use of mobile learning is, in turn, contingent on the extent to which students are permitted – and even encouraged – to use smart mobile devices for their learning. For example, in a collective case study of several school contexts exploring the recent rapid uptake of personal devices ("most notably, tablets") the authors note that in spite of growth in the number of students with smart mobile devices, their use in learning contexts needs to be properly established before further affordances may be realized:

> *In one year's time, the percentage of middle school students with tablets jumped to 52 percent, a doubling over the 2011 percentage. Despite this proliferation of mobile devices in the hands of students, schools are still reluctant to allow usage of such personal devices. Amongst high school students with smartphones, only approximately half say they can use their device at school (36 percent of 9th graders and 42 percent of 12th graders). Only 9 percent of all students say they can use their personal tablets at*

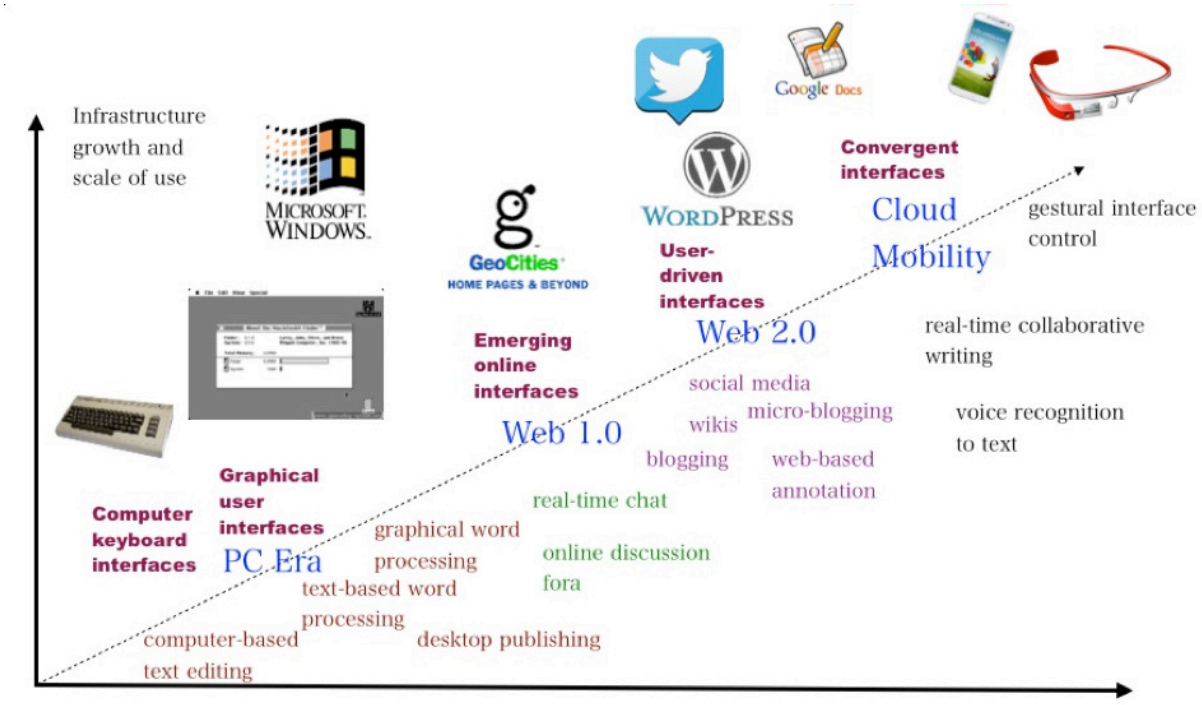
> *school… Today's digital learners are, therefore, caught in the cross hairs of a new mobile device dilemma. If you have a mobile device, you are probably not allowed to use it at school (Project Tomorrow, 2012, pp. 4–5).*

Thus, in spite of rapid growth and unprecedented access to highly sophisticated, portable and low-cost technology, exploring the educational use of mobile devices remains a key challenge for future educational research. As Pilgrim, Bledsoe and Reily (2012) point out, "although schools and universities are investing in technologies such as the iPad tablet, educators are struggling to keep pace with the speed of technological development and demand" (p. 16).

4. From Text to Speech and Gesture

While attempts to explore the affordances of mobile devices have been marred by their comparisons with traditional computing tools, it is important to note that device interfaces have changed to the point where the ways tablet devices are used represent a considerable departure from longstanding interfaces such as the computer mouse (over forty years old) and QWERTY keyboard (over one hundred years old). More importantly, this departure reflects the broader historical trends from text-based interfaces to visual interfaces. While the preference for these older interfaces persists in many learning and workplace contexts, when compared with the more visual interfaces of gesture, speech and touch on smart mobile devices, their use also serves as a reminder to avoid judging tablet devices on how well they achieve traditional computing tasks.

Figure 1 illustrates the evolution of device interfaces in relation to multimodal forms of representation. In particular, the diagram shows the proliferation of options for creating content in terms of hardware/software interfaces that support earlier keyboard and mouse (graphical) input alongside more recent developments in voice recognition and gestural control. Further, where computing in an earlier PC era was largely device specific and "disconnected," opportunities now exist to collaborate and communicate through a range of always-on, highly connected Web 2.0- and Cloud-enabled devices and convergent interfaces.



(Image used with permission: Hedberg & Stevenson, 2013, p. 20)

Figure 1: Text to Visual: Evolution of Device Interfaces and

At the same time as tablet technology has expanded the range of educational affordances and options for interacting with new interfaces such as voice recognition, gesture and touch, questions around the effective use of these devices in school settings remain. As Foote (2012) notes in a study exploring the 1-to-1 deployment of iPads in schools:

> *Will the iPad's portability, ability to be personalized, and functionality impact its effectiveness in a school setting? In answering this question, so much depends on the purposes for which it is intended, the pedagogy accompanying its use, training afforded to teachers, the methods for implementing the new technology, and the tech support provided (p. 15).*

5. Visualizing Solutions: Exploring Apps in the Classroom

Accompanying the changing technologies, is a changing approach to software deployment. This trend sometimes called "atomization" refers, on one level, to the separation into multiple, smaller applications ("apps") of software traditionally grouped together in legacy software suites. Examples of this include numerous software-as-a-service (SaaS) applications available online through Web 2.0 and Cloud services, many of which see a wide-scale movement away from traditional computer uses such as word processing in productivity suites like "Office" suites. On another level, Atomization is particularly prevalent on smart mobile devices, where emerging uses of the device itself – including its mobile nature, the touch- and gesture-based interfaces, cellular Internet connectivity and other features like accelerometers and cameras – are coded into small apps, hundreds of which may be installed on any one device. The low-cost nature of these apps (many of which are free, others usually little more than a few dollars) means that educators and students have relative freedom to explore their affordances and, more importantly, sequence them meaningfully together in a diverse range of learning activities. In other words, the "atomized" nature of the available apps informs the flexibility with which they may be integrated into both current and future literacies.

There are now arguably an overwhelming number of apps available to teachers and learners. While some of these have been developed primarily for educational use, others used outside of education have been appropriated for their educational relevance. By contrast to many traditional desktop applications – where training and manuals have often marked the learning process – teachers and learners usually learn how to use apps through experimentation, play or trial and error. While this form of participatory learning (Clinton, Purushotma, Robison, & Weigel, 2006) often reflects free learner inquiry in many online contexts, in practical terms it is not possible for teachers or learners to become expert in the use of every app, educational or otherwise. The sheer number of apps available therefore presents both conceptual and practical challenges for educators seeking to visualize and explicate the learning process. As with their deployment of mobile technologies, many schools have responded differently to the challenges presented by an overwhelming array of apps, often involving teams of teachers comprehensively exploring affordances, aligning use with curricula objectives and scaling use across classrooms and grade levels. Some schools have chosen to mandate a set of "core apps" for common purposes across the school context, others leave the decisions about which apps to use in the learning process up to individual teachers and learners.

There is a small (but steadily growing) body of research on the educational use of apps in the classroom. While several studies point out the benefit of apps for learning (Crichton, Pegler, & White, 2012; Culén & Gasparini, 2011; Geist, 2011), others highlight a range of issues to be addressed. Research has, for example, considered the challenge of making meaningful use of apps when such a large number often overwhelms the selection process. In one review of four thousand mathematical apps on iOS (more apps than any teacher, learner or school could conceivably explore), Bos and Lee (2013) disappointingly found that "most are simple flashcard, numeric procedures of mobile textbooks… and do not support sense-making… active learning, or integrated visual models" (p. 3655). Related findings by Highfield and Goodwin (2013) suggest the limited range of pedagogies evident in apps and dominance of instructional and fluency-based apps is problematic for teachers. Similarly, in a general review of educational iOS apps that rated apps on several criteria including grade relevance, content area, curriculum standards and customer ratings, Watlington (2011) reports mixed results, with a maximum 50% of apps linking to relevant curriculum standards, subject areas and grade levels. The review also notes that while some areas such as English language, literature and the arts are reasonably well represented, others – Science, languages other than English and music – appear considerably less so. In other studies exploring the use of Android apps, White and Turner (2011) note the potential of the Android as a more open platform for coding and app development – encouraging learners to more fully explore the device as programmers. However, as Peng et. al. (2012) point out, when compared with iOS, the Android platform remains considerably prone to many malicious apps, with users (especially children) often granting apps control over core features of the device and increasing the risk of misuse and malware. Overall, the general lack of robust studies of Android devices in educational settings is itself a challenge for future research.

In spite of these challenges, the learning benefits of apps – in what is now a changed technology paradigm – are apparent. Early research identified the potential for more personalized, situated and often "just-in-time" learning given the diversity of available apps and their relative ease of use on highly portable devices, arguing that the technology can often be "invisible within the learning experience" (Melhuish & Falloon, 2010, p. 6). Likewise, Whitehouse (2011) describes the development of the concept of blurred learning, which she refers to as a seamless environment with learners "often working synchronously across distance and at the same time working face-to-face with a group" (p. 145). Noting the relevance of iPad apps in teacher professional learning, Chandler and Redman (2013) discuss connected, collaborative ways of note-making, concept mapping and ideas sharing amongst teachers, suggesting that the iPad is "a tool that can support social, collaborative and exploratory communication experiences" (p. 61). These findings underscore the potential of apps, when used meaningfully, to provide immersive, situated and social learning experiences with very few technical barriers to their use, compared with those often present in more complex operating systems, or inherent when working across complex platforms and devices.

Functional literacy is arguably a key area in the literature where immersive learning experiences with smart mobile devices are well reported. For example, exploring a range of apps for English as a Foreign Language (EFL) learning, Meaurant (2010) draws attention to the confluence of the well established industry for EFL studies in South Korea and very high levels of technology use in what is commonly regarded as "the most wired nation on earth" (p. 224). This study of iPad apps for EFL learning in several colleges found that the availability of English language apps and the portability of iPads are especially useful for typical EFL classroom settings, where students "often alternate between whole-class activities and diverse individual, paired and small group tasks" (p. 228). In another study of illiterate migrants in Switzerland, Knoche and Huang (2012) found that participants – who could not read or write in either their native or adopted languages – nonetheless formed ways of expressing themselves and their identities through their smart mobile device, essentially using the tool as a bridge to the visual forms of expression that were available to them.

Exploring literacy for native English speakers, Hutchison, Beschorner and Schmidt-Crawford (2012) similarly emphasize the important relationship between tablet use and new media literacies as situated, embedded practices (Lankshear & Knobel, 2007). They note that the digital texts (increasingly in the form of iPad apps) are more oriented around literacy as doing, and as such, require different skillsets to decode, analyze, interpret and compose:

> *One way the iPad provides potentially useful opportunities for literacy classrooms is through digital, interactive books. However, it is important to consider that digital texts, as compared with printed texts, offer different affordances that create new modes of reading and writing. Accordingly, digital texts can require different skills, strategies and dispositions, collectively referred to as new literacies to read and navigate them. Thus it is important that teachers understand these differences and integrate digital technology into the curriculum to provide students with opportunities to learn these new literacies (p. 16).*

Given the increasing popularity of eBooks, including the growing collections of highly interactive and multimodal e-textbooks, educators will no doubt continue to explore tablet devices as tools for enhancing literacy experiences, engaging reluctant readers and redefining the nature of the "book" in the twenty-first century. However, an important corollary to be considered when exploring literacy as doing through the use of mobile devices and apps is learner creativity. Foote (2012) draws attention to the creative power of the iPad, noting that in many educational contexts, "it has spurred creativity… because of the [still] camera, video camera, and the apps that can be used for creative storytelling and video production" (p. 16). The use of apps for creativity has prompted further development particularly in the area of Digital Storytelling, now considered a well established mode for new media literacy in the classroom (Ohler, 2013). For example, in their study of iPad apps Storykit and Storyrobe for Digital Storytelling in upper elementary school classrooms, Reid and Ostashewski (2011) found that students demonstrated high conceptual understanding and creativity using these apps, and that students of all abilities "found success with the iPads in a number of ways." The study further reports that students were able to integrate the use of other apps such as Speak It! to build audio material to incorporate into their projects, noting that their confidence and abilities to work independently improved while teachers felt comfortable with not needing, as one teacher put it, "to be the guru of technology" (p. 1664).

Pilgrim, Bledsoe and Reily (2012) also explore the relationship between improved learner confidence and the increased number of ways to demonstrate literacy through creativity apps, drawing particular attention to apps that enable learners to demonstrate and "teach":

> *Apps can serve as portable interactive whiteboards. ShowMe, Educreations Interactive Whiteboard, and ScreenChomp are free downloads that record pen strokes and audio simultaneously. Then the user can post the recording online for others to access. These features can be used in any content area but are especially helpful in recording math problems with audio instructions. Students can also record their own audio or video clips to demonstrate understanding (p. 19).*

Finally, in a longitudinal study that explored iPad deployment and use in a large, K-12 setting, Gasparini (2011) found that device ownership was a very large factor in students making meaningful, sustained use of apps on what was considered "their" device. This use was contrasted when iPads were simply deployed in trolleys and available for classroom use alone – an argument that lends considerable weight to the Project Tomorrow Report findings on the importance of students personalizing their devices (Project Tomorrow, 2012). Gasparini's study found that in relatively short time when given the opportunity, students were able to personalize their devices with appealing themes, colors and additional apps that they considered appropriate for their learning. The visual nature of this personalization is evident with the range of screenshots taken a short time after students were allocated their device:

(Image used with Permission: Gasparini, 2011, p. 33)

Figure 2: Personalized Apps, Layout and Themes on Student-Owned iPads

The study further reports that, with the provision of personal devices, students could more freely choose apps that were both relevant to the task and supportive of their learning needs. For example, when working with digital stories, some students chose to use different apps for the task, and were able to reason why:

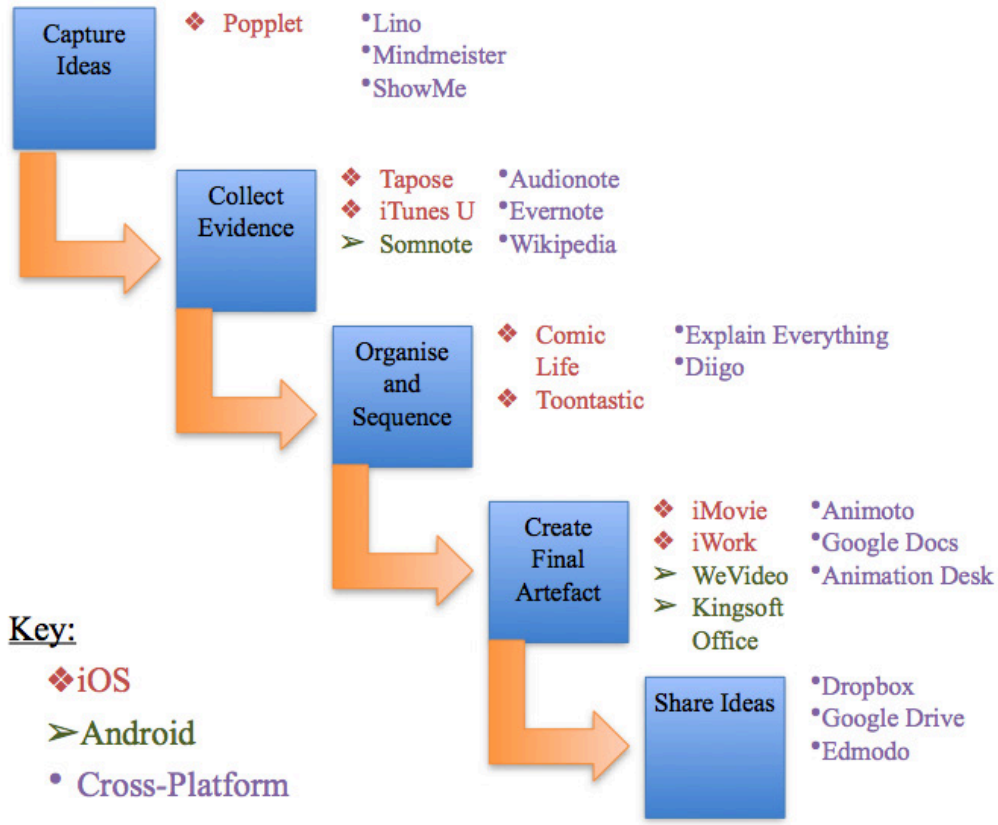
> *What made the difference here was their perception of their own ability to capture the object that was to be animated. The iPad's touch interface did not remove this barrier. The children who had problems with drawing were drawn to Puppet Pals, as they felt that their creativity could be expressed through the story itself rather than through the drawing of the story's characters. This was highlighted by one child's statement: "You know they have in some way draw it for you, so if you are not so good, you manage to make a story anyway!" (p. 44).*

In light of the enormous potential for apps in the classroom, further theorization and discussion of how learning processes are conceptualized is warranted. In particular, the visualization of the learning process represents an important consideration in meaningfully sequencing apps to align with twenty-first century pedagogies, while overcoming challenges and realizing most – if not all – of the learning benefits canvased thus far.

6. Pragmatist Theory and Apps as "Cognitive Stepping Stones"

Regardless of how apps are discovered, explored and integrated into teaching and learning, there is arguably a need to address where they fit into key stages in the learning process. This section of the paper examines the

potential of open-ended and "constructive" apps as tools in a visualized learning process. A sizable body of research has explored the importance of visualizing and verbalizing learning processes to enhance instructional design (Sweller, 2002), aid language comprehension and scaffold thinking (Bell & Lindamood, 1991), or as a way of teaching students cognitive strategies such as "getting unstuck" and developing skills of metacognition (Loughran, Mitchell, & Mitchell, 2002). With so many available apps, visualizing the learning process is arguably more about presenting appropriate options for learners at different stages within the learning process. Figure 3 illustrates some of the possible ways of configuring current apps for different stages of knowledge construction within a typical inquiry process. At the time of writing, a number of high quality apps that were first developed for iOS have been ported to Android. Figure 3 indicates whether the app runs on iOS, Android or both platforms ("cross-platform"). While future research might explore the potential of the emerging Windows Mobile platform, much of current app development is focused on the two current dominant platforms:



(Image used with Permission: Hedberg & Reeves, In Press)

Figure 3: Apps for Learning Processes

As represented above, visualizing the key stages, processes and options for the learner often reflects the research paradigm, instructional model or learning theory. Learner-led inquiry is a common feature of many current technology-mediated instructional models such as Inquiry-Based Learning (Owens, Hester, & Teale, 2002), Project-Based Learning (S. Bell, 2010) and Cooperative Learning (Kagan & Kagan, 1994). This form of inquiry (for example, as part of the process depicted above) arguably traces its theoretical roots to pragmatism and the work of John Dewey, for whom learning is grounded in activity and experience. Dewey (1916) saw the development of human knowledge as an adaptive response to the environment, arguing that learning "cannot take place by direct conveyance of beliefs, emotions and knowledge… it takes place through the *intermediary* of the environment" (p. 12, our emphasis). Accordingly, he defined the environment as "whatever conditions interact with personal needs, desires, purposes and capacities to create the experience which is had" (Dewey,

1938b, p. 43), suggesting that both change within the self and the environment occur through a dialectical relationship.

Dewey emphasized the importance of learning tools that emerge from shared social concepts (Eldridge, 1998). As Glassman (2001) elaborates, Dewey's "socially-developed tools… serve as reference points for the individual as she attempts to navigate life situations," but, importantly, "when the tools no longer have pragmatic value they are modified or rejected by the individuals using them" (p. 5). In many ways, Dewey's idealized form of learning is problem-solving through free, learner-directed inquiry, which he saw as "the self-controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (Dewey, 1938a, p. 108). In this context, pragmatist epistemology has often been associated with design thinking, or learner experience that involves the design of solutions through the inquiry process.

Apps encourage the implementation of design thinking and creativity as the learner moves through each stage of the inquiry process. As Figure 3 suggests, this often involves effective sequencing of apps for specific purposes, but should also involve critical thinking about which apps are best fit for purpose at each stage. When combined in meaningful sequences, apps enable the transformation of data from one representational form to another, supporting development of multiliteracies through multimodal forms of representation and interpretation. Alongside representation, appropriate use of apps in the inquiry process can support the learner's conceptual understanding, providing tools for the scaffolded development of ideas to frame increasingly complex thinking. For example, cross-platform (iOS/Android) apps such as Lino and Mindmeister support ideation through scaffolding ranging from semi-structured to highly structured, while ThinkPal suggests thinking strategies based upon the learner's current cognitive impasse and Star Walk enables the learner to scaffold direct experiences as they point their camera to the heavens and gain assistance interpreting the sky they are observing.

As Pilgrim, Bledsoe and Reily point out, "varied digital technologies provide teachers of any content area with a different approach to integrating the skills of the 21st century" (p. 17). By visualizing apps as cognitive steppingstones in the learning process, teachers and learners are encouraged to incorporate a wider range of skills and modalities into the learning task. Hutchison, Beschorner and Schmidt (2012) explore the technology and literacy skills required in the transformation of data in different representational forms. In their study, upper-elementary students used a range of iPad apps to visualize, order, interpret and represent meaning when responding to and composing written texts. For example, during the visualization stage:

> *…the researchers located an iPad app called Doodle Buddy that students could use to draw their illustrations. This app was selected because of its intuitive interface and drawing features that create the effect of using many different drawing tools, such as colored pencils, chalk, paint brushes, glitter, stamps, and so on. The app also allows users to insert photos, undo their last action, and easily alter between multiple tools and colors. Additionally, drawings can be exported through e-mail or saved to the iPad photo album so that the drawing can be viewed later or inserted into a different app (p. 18).*

Further, the researchers employed the use of Popplet to "represent the main events in the [learning] sequence, connecting them with time-order words." To enhance their retelling of the narratives, students sequenced and annotated their illustrations in Strip Designer, while Sundry Notes was used to explain cause and effect in the narrative by inserting students' audio comments on an instructional-level text to explain their understanding. As one child noted during interview, using apps like Popplet "helped with comprehension, because we picked out main ideas and when we had to put them in order," while another child noted that using apps to annotate text and images meant that, "you have… a reason to think about the book instead of just like letting it kind of go over your head and… not remembering anything." (pp. 19-20).

In another case study of iPad apps in an upper-elementary Social Sciences classroom, Berson, Berson and McGlinn-Manfra (2012) discuss the potential of the iPad as "a conduit for fostering classroom community building as well as promoting social studies learning goals" (p. 88). In particular, this study looks at the sequencing of apps and visualization of the learning process in an inquiry unit on the Caribbean and the effects of the 2010 earthquake on the region. In a largely teacher-led series of activities (limited by the availability of only three iPads among the fifteen students), the class primarily used the app My Haiti: Valdo, a Child's Story to generate empathy for victims and survivors of the earthquake. Students then linked this empathy activity to a range of apps for different purposes and modalities with a view to expanding their understanding of the

issues and actively researching answers as part of the learner inquiry process. Figure 4 demonstrates the form that this learning process took, including how the apps were employed as "puzzle pieces" in the larger learning process:

(Image used with Permission: Berson et al., 2012)

Figure 4: Visualized Learning Sequence in Social Studies Inquiry Learning

Interestingly, the process depicted here reflects the use of a wide range of apps, interfaces, modalities and literacies while not specifying a clear sequence, often a feature of many project- and inquiry-based learning models (Buck Institute for Education, 2014; New Tech Network, 2012). This process culminated in "writing stories that depicted the effects of the 2010 earthquake on the region, using multiple apps to support their creativity, collaboration, and communication" (p. 88), but integral to the success of the final task was the need to develop a diverse skillset through the apps employed.

As these examples demonstrate, visualizing and sequencing the learning process through the meaningful use of apps has the potential to support twenty-first century pedagogies and extend the range of digital skills and new media literacies. When combined with the low technical barriers to using apps, the portability and growing affordances of tablet devices, there is potential for creating highly immersive and collaborative learning environments with "invisible" technology and a clear focus on authentic, situated, learner-led inquiry.

7. Frameworks Moving Forward

In the years before the impact of highly personal, smart mobile devices, the focus on technology in educational institutions has dwelt on the expensive and relatively fixed technology infrastructure necessary to enable unified ways of learning within the institution. In many cases, the choice of specific hardware often dictates the software used in education. For example, institutions choosing to deploy computers (running under MacOS) provide access to specific tools that many learners have come to associate with creativity (GarageBand, iMovie), whereas the decision to deploy Microsoft Windows-based PCs provides access to software often associated with productivity (Microsoft Word, Excel or PowerPoint). These decisions often reflect the reality of a learning environment that is, to a fair extent, centrally controlled and administered, for example, by IT personnel who may be removed from teaching and learning strategies. Their decisions have held implications for key infrastructural, pedagogical and broader organizational changes within the institution, such as the many 1-to-1 technology device programs, the use of specific hardware and software for instructional delivery such as interactive whiteboards (IWBs), data projectors, and computer laboratories. Most often, the emphasis is on common, or agreed technologies and standards that are deployed throughout

the institution; their use may be encouraged, or even mandated, and alternative technologies might be discouraged, or even "blocked." While representing an older paradigm, the legacy of infrastructure-led designs still persists today.

In many ways, however, the rapid development and wide scale adoption of mobile devices represents a marked departure from these infrastructure-led designs. While many educators and institutions have continued to wrestle with understanding, implementing and supporting a growing number of tools, platforms and standards, the impact of overarching, multi-platform trends like Cloud- and Web 2.0-based technologies point to the idea of what some have predicted and now regard as "device agnosticism" and "convergence" (Garner, Zoller, Trotter, & Anderson, 2005; Prince, 2011). For example, iOS, Android, MacOS and Windows apps like Evernote (a tool for storing, cataloguing and tagging notes and media), Dropbox and Google Drive (tools for saving and retrieving files using online storage) all enable content sharing across devices and platforms – and these tools have become the bedrock of many successful Bring-your-own-device (BYOD) initiatives (Eschelbeck & Schwartzberg, 2012; Grussendorf, 2013; Romer, 2014). As we have seen, there are a rapidly growing number of web-based, Web 2.0 and mobile apps that also emphasize people-to-people interaction, very often occurring in real-time and without the need to assume the same physical space. As our personalization of technology devices and tools deepens at the same time as increases to the number and scale of our interactions with others online, many have come to expect that much of our data will be accessible 24/7, from any device, stored "in the cloud." These realizations present enormous opportunities at the same time as presenting considerable challenges.

In drawing conclusions about their students' use of a wide range of apps, Hutchison, Beschorner and Schmidt (2012) maintain that "teachers should select appropriate activity types and assessment strategies before making a final selection about which technology tool will be most useful" (p. 21). By designing the learning task as, in a way, independent to the technology, the teacher is arguably better equipped to carefully and purposefully select apps as cognitive steppingstones within the learning task, resulting in tasks that more consistently challenge students to develop a wide range of digital skills. Goodwin and Highfield (2013) also highlight the key role of the teacher in the teaching and learning process. They suggest that teachers examine the underlying pedagogy of the technology they select and focus on aligning the pedagogic design of the technology to their intended classroom goal. Berson, Berson and McGlinn-Manfra (2012) note, through the use of carefully selected and sequenced apps, students "learn a new form of literacy as they move between apps and engage in both personalized and collaborative learning experiences" (p. 89). At the same time, by carefully framing the learning process with key stages and sequences, both students and teachers can more easily substitute apps. Such substitution may be necessary, for example, in cross-platform environments where different apps exist on different platforms, or in circumstances when new apps are released to replace older ones. One key element in the use of apps that is arguably imperative moving forward is the need for collaboration and communication across devices, platforms and networks. As this discussion has shown, market pressures have led to high quality educational apps being available for the dominant platforms, and this is a trend likely to continue. By promoting technologies that easily interface between devices – smartphones, tablets, desktops and laptops – educators better ensure that the future technology device debates are not "either/or," but "both/and" and support sharing and collaboration. At the same time, it is important to be mindful of what Rideout, Saphir, Tsang, and Bozdech (2013) term the "app gap," wherein lower-income children (ages 0-8) have more than 50% less experience using mobile devices than higher-income children in the same age group" (p. 10). Most importantly, promoting more learner-led solutions, for example, by embracing the many devices and platforms that students already have, schools can avoid the limitations of legacy infrastructure-led solutions that impose a non-pedagogical technology solution on learning.

8. Conclusion

> *That education is not an affair of "telling" and being told, but an active and constructive process, is a principle almost as generally violated in practice as conceded in theory. Is not this deplorable situation due to the fact that the doctrine is itself merely told? It is preached; it is lectured; it is written about. But its enactment into practice requires that the school environment be equipped with agencies for doing, with tools and physical materials, to an extent rarely attained. It requires that methods of instruction and administration be modified to allow and to secure direct and continuous occupations with things (Dewey, 1916, p. 36)*

This paper has reviewed some of the many challenges and opportunities that line the journey towards schools using smart mobile devices for authentic, situated and immersive learning. By critically examining the use of apps as part of a pragmatist theoretical framework for smart device mobile learning, we argue that these technologies function as tools for learning grounded in experience, purposeful action and inquiry. Parsons (2014) has suggested that the future of a world of smart devices with focused apps to support cognition enables new pedagogical strategies that:

1. place learning in specific contexts and the device with its apps enables the learner to collect, organize and share with the one device;
2. overlay reality with virtual information;
3. no longer simply follow a highly pre-structured path but enabled to contribute to the creation of shared learning resources;
4. provide an adaptive toolkit in the palm of the hand. One that enables the user to include spatial data and track the source of changes; and
5. enable the learner to take ownership of their learning (2014, pp. 221-223).

Inherent in this position is the importance of promoting choice whenever possible. While some schools offer choice very broadly by encouraging students to bring in any device through BYOD, other schools implement whole-of-school technology programs that see the deployment and use of one main device. Regardless of the direction that is taken, the diversity of software platforms and apps now represents choice on a "micro" level at a "macro" scale. Students are, more than at any time in the past, able to determine which technology tools will be suitable for each stage of the learning process. With recourse to the case studies discussed, this paper has shown that choice can operate in a number of ways. At the same time, many schools maintain large infrastructure-led solutions where specific hardware and software are mandated, representing environments where it remains very difficult to capitalize on the benefits of personalized mobile devices. Nonetheless, it is important to remember that the education community has an important voice in technological change. Just as Dewey argued that the makers of the tools should not dictate how they are to be used, educators and learners have a responsibility to challenge technology giants and software developers to meet their needs in a changing world. By visualizing learning processes and exploring apps as cognitive steppingstones, teachers and learners are more able to recognize what they need from technology and work pragmatically and openly to address these needs for many years to come.

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