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Facilitating guided participation through mobile technologies: designing creative learning environments for self and others

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Abstract We appropriate Rogoff's (Apprenticeship in thinking: Cognitive development in social context, 1991; in: Wertsch et al. (eds.) Sociocultural studies of mind, 1993) notion of guided participation to demonstrate, through abbreviated case studies, our strategy for integrating mobile technology-based learning experiences in higher education. Guided participation implies facilitating access to shared community-valued practices by supporting new members in legitimate participation. We illustrate how mobile technologies and social software can be used to (a) facilitate guided participation among undergraduate engineering students within classes and (b) teach graduate students in instructional technology to design for guided participation. Thus, students are not only transitioned into respective learning communities but also gain experience in designing for others. Given the recent advances in computing and trends in the adoption, diffusion, and use of mobile technologies, we argue that mobile technologies provide a substantive, fertile, and invigorating area for teaching and research in higher education for the foreseeable future.

Keywords Guided participation · Instructional design · Mobile learning · Undergraduate or graduate education · Sociotechnical infrastructure

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Introduction

As information and communication technologies (ICT) advance rapidly through digital innovation, changes in learning and teaching infrastructure are unavoidable. To some scholars, this spells a challenge that competes with other resources in a classroom and must be approached with extreme caution (Cuban 2003), and to many scholars and practitioners, this affords a new opportunity to innovate education (Barron and Feyten 2008). Technological change requires resources, and its proponents have to compete for resources from the same pool as others; therefore, there is a trade-off involved that makes many stakeholders wary of change. Yet, in the last decade, the pace of technological advancement and the adoption of technology by the population at large has changed the questions of "whether technology" to "when and how" (Schneider and Evans in press).

We argue that the time for technology implementation and related innovation, especially as it pertains to mobile technologies, is now. But if mobile technology is to make a significant positive impact on learning, we have to design not just the features of the devise but also the social and physical infrastructure around the devise (Bielaczyc 2006; Evans in press; Star and Ruhleder 1994). In this article, we first review the current advancements in mobile learning technologies and then present two case studies of technology: the implementation of the Tablet PCs in large classes and the use of mobile phones in Malawi, Africa. The learning objectives, domains, content, and settings for both case studies are different, highlighting the diverse ways in which mobile technologies can support learning objectives in higher education settings. The first case focuses on building a learning environment for students; while the second case describes how students learn by building a learning environment for others. Overall, we argue that in addition to just-in-time access to information, mobile technologies allow the establishment of a learning ecology that transcends physical and social barriers by allowing access and sharing of multiple representational forms, thereby providing a unique, adaptable, and tailored experience to each user (Lee and Chan 2006; Pea 1999).

Guided participation: leveraging the sociotechnical infrastructure

The social and constructivist aspects of learning now form a core aspect around which learning environments are designed, with active, collaborative learning emerging as a legitimate model for learning (Greeno 2006). Our theoretical underpinnings come from the same tradition but are specifically embedded in the embodied sociocultural tradition of teaching and learning. In particular, we draw on the guided participation perspective proposed by Rogoff (1991, 1993) whose work focuses on informal learning settings to examine experiences, such as the progression of Girl Scouts as they become sophisticated cookie sales agents. Rogoff proposes three planes of sociocultural activity: *apprenticeship*, *guided participation*, and *participatory appropriation*. Here, we use guided participation as the foundation for research and design in higher education. Guided participation refers to means of access to specific, community-valued practice that is organized by shared goals. Guided participation describes the explicit and implicit rules, recipes, spontaneous feedback, and workarounds appropriated by new members desiring to participate more fully. Most importantly, guided participation highlights the need to connect more knowledgeable members with novices and encourages members to adopt diverse roles, referents, and devises while developing an understanding for future contribution. Specific instructional strategies include team-based learning, mentorship roles, informal interactions, and access to local and field expertise (Schneider and Evans in press).

Mobile technologies in education, performance support, and society: recent trends

Mobile learning has received much attention of late in diverse educational settings for several reasons (Evans in press). In primary and middle schools, mobile learning is being used to instantiate "learning by doing" and "knowledge building" pedagogies (cf., Scardamalia and Bereiter 1994), encouraging students to collaborate inside and outside the classroom with mobile devices for data collection, analysis, and communication. Examples of such applications include middle school students using GPS-enabled handheld computers to collect audio, video, and location-based environmental data in a natural science course (Klopfer and Squire 2008) and elementary students monitoring a school garden using a Web-enabled smart phone to collect and share text, photographs, and video with an agriculturalist providing expert guidance and feedback (Evans et al. 2008a). In corporate, healthcare, and military settings, where a significant number of employees are field-based, mobile technologies are used to deliver location-based and time-sensitive information, real-time updates, and job aids. For example, in the healthcare field Tablet PCs are being used by nurses on rounds to update patient data and records. In military settings, electronics technician's shipboard are receiving updates to technical manuals and conducting real-time chat with shore-side experts via ruggedized pocket PCs (Evans and Schwen 2006). Finally, mobile learning is taking hold in developing countries where access to desktop and laptop computers is severely limited, and electricity is intermittent, necessitating a reliance on mobile phones. For example, in Malawi, Africa, cell phones are used as a ubiquitous platform for education, research, journalism, and commerce (Evans et al. 2008a). Overall, mobile technologies are infiltrating a broad spectrum in education, performance support, and society, catching the attention of teachers, researchers, administrators, policy makers, and mobile, wireless device manufacturers. It is against this backdrop that we present two abbreviated case studies on mobile technologies in higher education.

Case study 1: Tablet PCs in engineering education at Virginia Tech

Meaningful guided participation and the ability for self-expression are critical components of the learning process (Cobb et al. 2001; Rogoff 1991; Suthers and

Hundhausen 2003). One unique challenge faced by many institutions in implementing these ideas, and particularly in facilitating participation, is the increasing class sizes in most public and private higher education institutions. Large classes, often held in lecture halls, limit the ability to monitor gestures and facial expressions of students, which are essential for communication and joint activity. Thus, it is difficult to establish common ground to engage students with representations such as text, diagrams, and visuals, within the class. At Virginia Tech, one of the ways to solve this problem is by using the mobile platform of Tablets PCs in conjunction with the networked software DyKnow (http://www.dyknow.com). Tablet PCs are unique since they combine high computing power with direct pen-based input, providing users with the affordance (Norman 1990) to engage in several design activities such as sketching and ideation directly to the digital medium and allowing simplified storage, manipulation, and exchange of creations. This affordance is especially crucial for the sciences and engineering due to the varied representational systems such as equations and diagrams used in these disciplines. DyKnow augments this affordance by supporting hundreds of concurrent users and allowing them to collaboratively take notes and interact. Each user can draw or write on a slide or panel individually and also receive the writing done by the instructor. Figure 1 gives a quick glance at the DyKnow interface. Through DyKnow, students can draw representations directly on their computer, add to the representation presented by the instructor by creating their own representations, and share their representations back with the instructor and the class, thus facilitating guided participation.

Guided participation through representational mediation

Through their affordance for representational practices DyKnow and Tablet PCs are central to our ongoing efforts to improve student learning in the freshmen-engineering program at Virginia Tech (Johri and Lohani 2008). These technologies, when used in tandem, allow the creation of meaningful interactions between faculty and students around representations produced by the faculty and the students (Alterman 2007). We, the instructors, prepare panels in advance by using PowerPoint and then transfer the slides into DyKnow. Often we write on panels

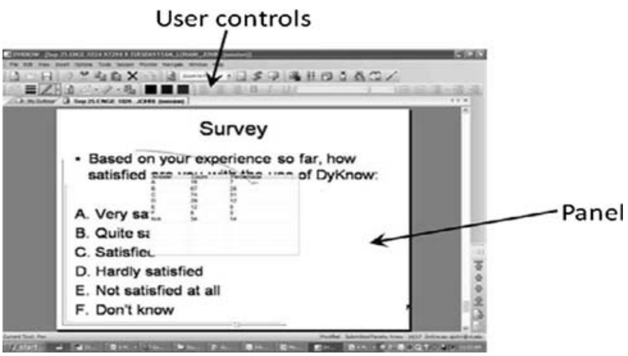

Fig. 1 The DyKnow interface

beforehand using purple ink, which is only visible to the instructor even when the panel is shared, and then create elaborations on the panel. Different inks are used to convey different ideas (blue = right, red = wrong) and draw attention to certain portions of a slide dynamically by using a flicker devise. Large classes can provide a public forum to share individual work and highlight students' efforts (Wolfman 2002); we use this opportunity frequently. We ask students to submit their panels and select some panels from the responses to share back with the class. Our in-class survey results show that students like "the feature allowing the instructor to write on the panels" (57%, $N = 75$), and the majority of students (70%, $N = 163$) either "agree" or "strongly agree" with the statement that "they like the ability to write on the panels." Figure 2 shows DyKnow in use for previewing student panels and collecting them for sharing with the class. On the left is the list of student from whom the panels have been selected for previewing. DyKnow also has synchronous polling functionality that we use in class to gauge the opinion of students (whether they think someone behaved ethically in a case study we discussed), get feedback about the class and the software (do they like a particular functionality), and quiz students on multiple-choice numerical questions. Through another software feature, we ask students to display their status of understanding, that is, how well they understand what is being taught. This information appears on the instructor's screen as a pie chart in three colors: red denotes lack of understanding, green represents understanding, and yellow suggests being unsure. Increased awareness and visibility of student performance helps the instructor identify concepts that need to be repeated or reinforced. Figure 3 shows a panel where the second author is teaching

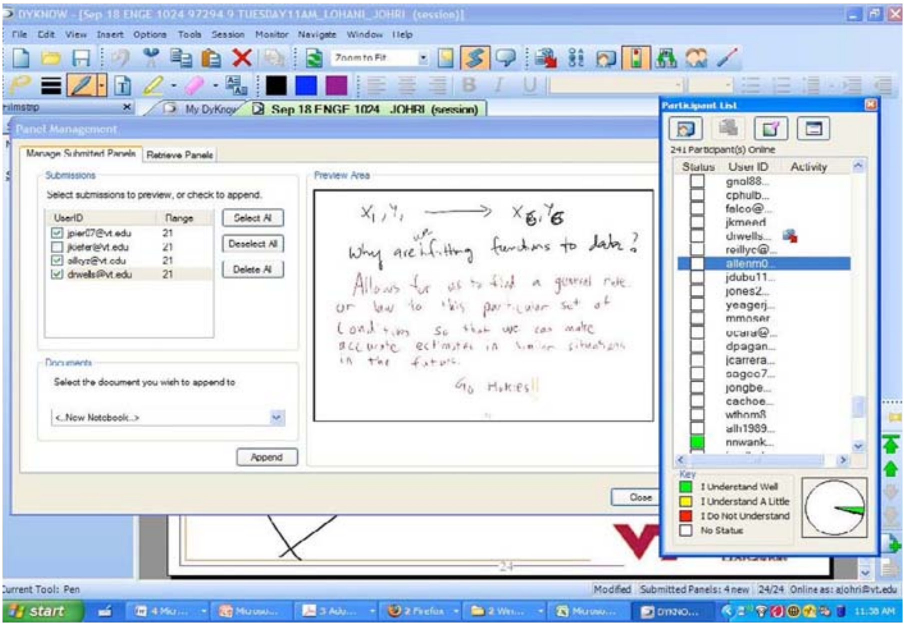

Fig. 2 Previewing and collecting student panels and looking at participants

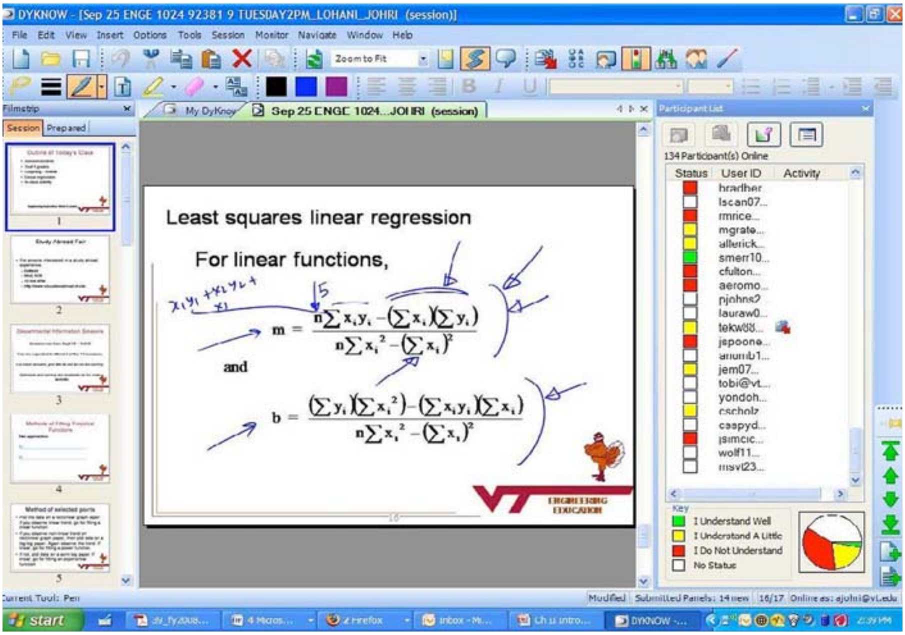

Fig. 3 Lecture slides (*left*), explaining a formula (*center*), and student feedback (*right*)

linear regression concepts by drawing representations on the panel. On the right is the status panel where the red color represents the students who selected “I do not understand” on the status indicator. In this example, it can be seen that several students indicated their inability to understand linear regression concepts that were then addressed by reviewing the key concepts again.

DyKnow also proved efficient in incorporating formative assessment into instruction. For example, the instructors traditionally described the flowcharting process by developing an incomplete flowchart. This year we discussed flowcharting in the lecture and through DyKnow shared a blank panel with all students and asked them to draw the flowchart on their own for a given problem. We randomly collected some panels after about 5 min and projected the panels on a large screen through a projector and discussed various elements of the flowchart that were right or wrong or missing. We have implemented this strategy since then to cover a number of other aspects of the course. This preliminary account of use of pen-based computing hardware and software shows that large classes can be transformed through technology and made more inclusive and participatory. If we consider the class as a cognitive system, then the devises available for use within the class re-arrange cognition and learning. At first glance, DyKnow appears to be an extension of audience response systems such as clickers that have become increasingly common in higher education classrooms (Dufresne et al. 1996). But although DyKnow imbibes several features present in other audience response systems, such as polling, we argue that they go beyond these affordances by engaging students in a shared activity involving higher level thinking around representations created in class (Hall 1996). Through this process the technology transforms the practice of large classes by creating a discourse that is critical for appropriation of scientific and engineering practices (Penuel et al. 2006). The technology also facilitates mobility of students not only within the classroom—they can sit wherever they like—but also beyond the classroom as they can use most of the functionality even after the class is over. Several students reported logging into DyKnow from their dorm room, hospital, and even an airport lounge, giving a peek at the future possibilities for (a)synchronous mobile learning.

Case study 2: the Mobile Malawi Project

The principle goal of the Mobile Malawi Project (http://www.mmp.soe.vt.edu/) was to facilitate connections among community agricultural experts, primary school teachers, and science teacher educators using an innovative combination of mobile phones, low-bandwidth instructional multimedia, and Web 2.0 technologies including blogs, wikis, and content aggregators. The intent was to improve existing, paper-based curriculum on sustainable agriculture in Malawi, Africa, a sub-Saharan nation that annually suffers from drought and low crop yields. A stated goal of the primary school curriculum in Malawi requires children to learn from community members. Thus, we explored how mobile phones, instructional multimedia, and Web 2.0 technologies could be used to establish and nurture such connections. This project served as a case study to demonstrate how "teaching to learn" can be applied using mobile technology hardware and associated software. By designing a curriculum that involves a holistic approach to guided participation, graduate students in instructional design and technology learned the concepts as well as the practical aspect of implementing a specific pedagogical approach. Moreover, the most critical learning that emerges is the ability to take another person's perspective into account while in the process of designing.

Project context

The School of Education at Virginia Tech has a close to 10-year relationship with the Ministry of Education in Malawi and over 10 teacher training colleges (Kadzera 2006). Consequently, the Mobile Malawi Project (MMP) leveraged existing relationships with teacher colleges to facilitate connections among community elders, primary school teachers, and science teacher educators using mobile phone and Web 2.0 technologies to improve both the training of science educators and the teaching of sustainable agriculture in the primary classroom. In Malawi past research has shown that elders are a valuable source of knowledge for schools and villages. However, this knowledge has not been systematically connected to the school science curriculum, due to social and technical barriers. Establishing technological connections between indigenous knowledge and school curriculum is particularly important when posed within the context of developing nations that are struggling to modernize and improve the educational experiences of their citizens in the midst of widespread challenges—poverty, hunger, disease, lack of infrastructure, and environmental degradation. As most primary schools in Malawi have limited access to electricity and wired telecommunications, the potential for using mobile devices for educational purposes to access and create information is immense. For example, in the year 2000, Malawi had 49,000 cell phones in use, and by 2004 the number increased to 222,100. Mobile phones are being explored as a platform for delivery of instructional multimedia as critical for addressing the digital divide in developing countries such as Malawi, Africa (Evans et al. 2008a).

Design values: facilitating guided participation

Teaching science to all students requires understanding scientific worldviews and epistemologies of diverse cultures, as well as the conflicts and problems that students may experience when crossing cultural borders to learn western science. Although science is potentially a driving force for economic solutions to poverty, little attention is given to the cultural context in which science is taught, particularly in reference to indigenous science and technology of which the villagers are most familiar. Indigenous science represents descriptive and explanatory knowledge about nature acquired across generations from cultures with strong oral traditions (Evans et al. 2008b; Glasson and Evans 2007). Research in developing countries requires a perspective of understanding emerging technologies as not simply external devises but integral parts of socio-cultural practices within a community (Rogoff 1991, 1993). Although the current network infrastructure in many African nations is underdeveloped, mobile phones are prevalent in developing countries and are inherently democratic, as many poor people make sacrifices to pool resources within a community to purchase airtime for purposes such as conducting business in the market (Donner 2008). As mobile smart phones can now be used for maintaining communications, accessing computer networks, and capturing and delivering multimedia, there is vast potential for connecting African schools to the Internet for the first time and for using mobile devices as a data gathering device to share and communicate ideas within the context of their local culture.

Design considerations: the graduate course experience

The theoretical and contextual parameters were the basis for a graduate course in instructional media production taught in the spring semester 2008, led by the first author. A major deliverable for the course, EDCI 5784: Principles in Media Product Design, was to iteratively design, implement, and evaluate potential mobile and Web 2.0 technologies in a participatory manner through a guided participation approach where, "To *understand* development, it is essential not to impose assumptions about the goals of development of one group on individuals from another. Interpreting the activity of people without regard for *their* goals renders the observations meaningless" (Rogoff 1991, p. 117, emphases in original). For the course, our pedagogical goals were twofold. Firstly, we were teaching our students how to design curriculum but from the perspective of the learner, and secondly, we were providing technologies for unfettered knowledge building and communication within real-world constraints found in urban areas where teacher educators work and in poor, rural areas, where primary school teachers are found. For this project, the nodes of the network to connect knowledge cultures within Africa and in the United States include the following: (a) A community agricultural expert, Mr. Daniel Chinkhuntha, contributed knowledge of sustainable agriculture practices, including channel irrigation, composting, and organic pest control; (b) A science and agriculture educator, Dr. Wotchiwe M. Kalande, conducted field testing of mobile devices and sustainable agriculture curriculum with pre-service teachers; and (c) A primary school teacher, Mr. Timothy Banda, was selected from a primary science and agriculture class in Malawi.

The instructional media design class at Virginia Tech developed a sustainable garden curriculum based on elder knowledge. In an effort to establish a culturally diverse virtual team connected by mobile phone technology, a living archive was developed to share information and document the communication patterns and progress of the project. Blogs and wikis, using open-source software, WordPress (http://wordpress.org/) and MediaWiki (http://www.mediawiki.org/) were developed and implemented as distributed knowledge and communication platforms (Figs. 4 and 5). The Mobile Curriculum Connections Web site can be found at the following URL: http://bashful.cs.vt.edu/pmpd/. Moreover, taking the lead from projects such as MobilED (http://mobiled.uiah.fi/), we continue to explore text-, voice-, and multimedia messaging, and the potential of solar-powered devices, including battery chargers (Solio, http://www.solio.com/) and wireless outdoor routers (Meraki, http://meraki.com/).

Mobile learning in higher education: training the next generation of instructional designers

The Mobile Malawi Project permitted graduate students in the instructional design and technology program at Virginia Tech to apply theoretical and pedagogical aspects of guided participation in a real-world mobile learning context. The end result was the Mobile Curriculum Connections prototype that provides knowledge access and exchange over highly mobile devices—particularly smartphones, mobile Internet devices, and netbooks (http://www.dailybits.com/are-netwbooks-the-next-wave/). The Mobile Curriculum Connections project gave graduate students in instructional design the opportunity, under strict contextual and technical constraints, to design, develop, implement, and evaluate several iterations of a mobile learning application (Evans et al. 2008a).

Implications and future directions

In line with this special issue on mobile computing in higher education, the annual issue of the Horizon Report (New Media Consortium 2008) predicts radical changes in teaching and learning within the next five years as a host of emerging mobile technologies and digital media are adopted and diffused in formal and informal learning settings. Two trends identified in the report relevant to our position on

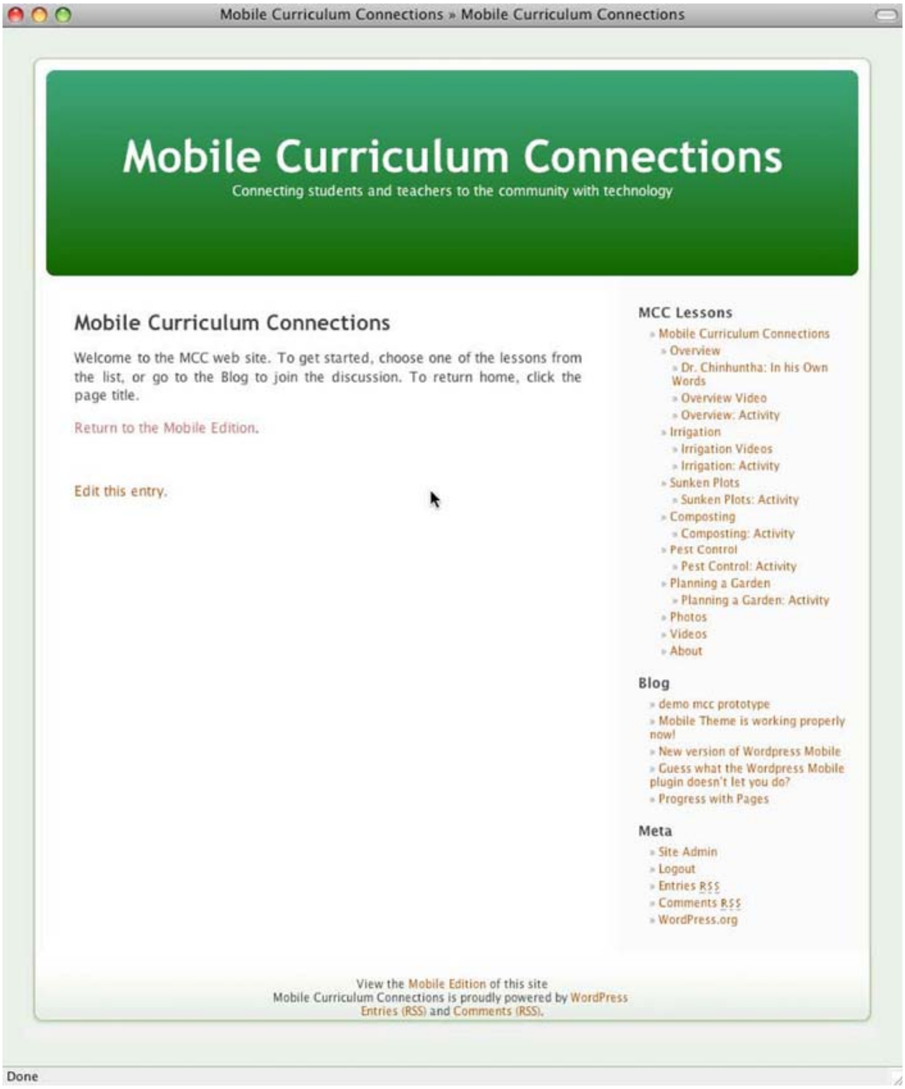

Fig. 4 Mobile Curriculum Connections formatted for laptop browsing

guided participation are the increasing role of mobile technologies in education and the changing expectations of learners toward information and knowledge. The argument is that these trends are, in part, founded on specific changes in how learners create and consume knowledge, and use emerging technologies (Evans in press). Our experiences as instructors using mobile technologies to guide participation into the engineering field (second author), and as a platform to develop curriculum using the guided participation metaphor (first author), have further justified the following precepts.

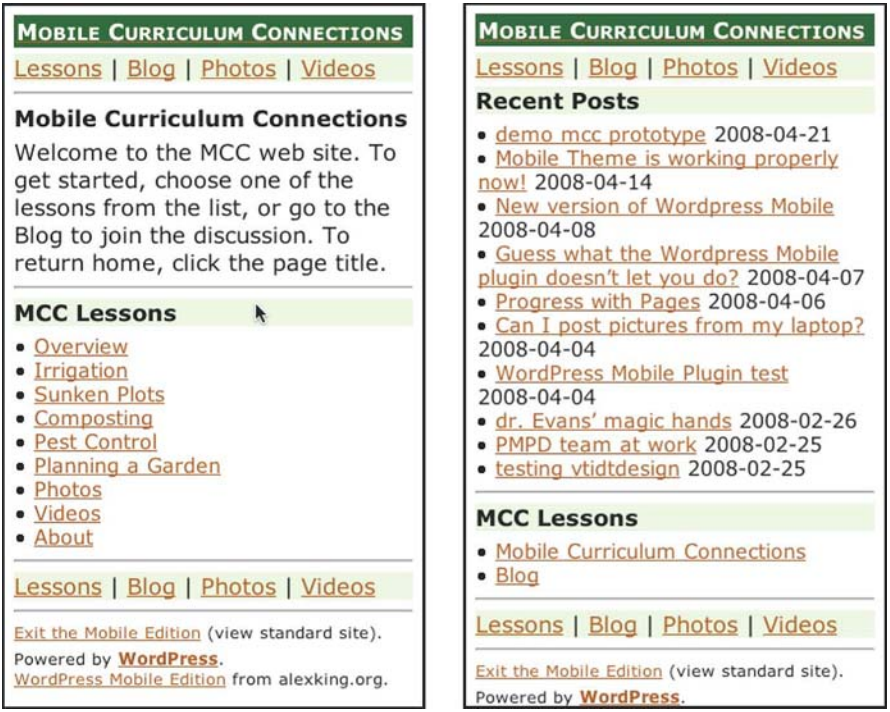

Fig. 5 Mobile Curriculum Connections (lessons on the left; blog posts on the right) formatted for mobile devices

Personal, mobile devices as primary point of reference for generation M

Mobile and personal technologies are increasingly viewed as a primary platform for delivery: Learners view mobile media devices—Tablet PCs, netbooks, and smart phones—as a first point of reference for information access. The Virginia Tech campus serves as an exemplar of the pervasiveness and influence of mobile technologies in higher education, inside and outside the classroom. Within the classroom, Tablet PCs and handheld computers are becoming standard supplies for entering college freshmen. Since fall 2006, every freshman entering the College of Engineering at Virginia Tech is required to buy a Tablet PC, Fujitsu LifeBook® T4000 Series, for program-related work. The devices serve as design sketchpads, lab notebooks, and a means to interact with instructors via surveys and student response systems. In the instructional design and technology program, instructional multimedia is designed, developed, and implemented on a wide-range of mobile devices including portable digital video devices, handheld computers, and smart phones (Evans et al. 2008a). Most notably, on the Virginia Tech campus, mobile devices now play a vital role for faculty, staff, and students. If one can find a positive outcome from the tragic events that occurred on our campus on April 16, 2006, it is that the university has established an emergency alert system, VT Alerts (http://www.alerts.vt.edu/), which exploits the pervasive use of mobile devices.

Customized experiences and open access to information and knowledge

Learners are expecting individualized services, devises and experiences, and open access to media, knowledge, and information: In contrast to the standardized, controlled models of information dissemination, the current generation of consumers demand customized services (Pea 1999). Again, the newly installed VT Alerts system highlights well the expectation of students to have open, individualized access to knowledge and information. When signing up for VT Alerts, a user has several options including the order in which different contact methods should be accessed and how that information should be delivered. For example, one user may select to have text messages sent to their mobile phone as a first order and a voice message sent to their home phone as a second. Another student may select to have instant messages sent to their mobile phone number as a first order and an e-mail sent to their campus account as a second. Though these services and information may be used infrequently, it is the individualized, open access now available that students demand (Evans in press). On a more broadly applicable scale, Virginia Tech has subscribed to iTunes U (http://itunes.edtech.vt.edu/), a podcasting distribution service offered by Apple, Inc. This service permits faculty to upload audio–video broadcasts of lectures to the iTunes store for download onto portable digital devices. Finally, as demonstrated in the Mobile Malawi project, open-source, multi-author software systems (blogs, wikis, and content aggregation services) have been leveraged for educational purposes. The design requirement was to facilitate customizability and open-access to students, teachers, and community members advocating guided participation (Evans et al. 2008a; Schneider and Evans in press).

Conclusion

Although mobile technologies are inherently thought of as devices that are portable by the user, current technological infrastructure allows for significantly more affordances. Current mobile technologies such as Tablet PCs and smart phones build on this platform and through supporting exchange infrastructure such as wireless, infrared, or Bluetooth allow users to readily share their creations and customized information. Therefore, although mobile technologies and infrastructure support small group collaboration, they also afford the opportunity for collaboration when users are not physically collocated. In many ways mobile technologies are leading to hybrid environments that make optimum use of physical co-presence as well as digital interaction. To use another example, Tablet PCs, by providing the affordance to draw on the screen using a pen, allow students to create freehand representations and sketches. This is very useful in subjects such as science and mathematics, which use equations and other notations. Design fields, which often require quick-and-dirty sketches, pixilated prototypes, and mock-ups, would also benefit. In addition, by being able to use the Tablets in laboratories as well as classrooms, students are able to create and recreate these representations and combine them with formal learning in classrooms.

Our predilection is to use Rogoff's (1991, 1993) concept of guided participation to direct development and implementation of mobile learning strategies. Whether it be *designing for ourselves* in large undergraduate classrooms to enhance the active participation of new members of the engineering discipline, or *designing for others* to establish and sustain connections among communities, neighborhoods, and schools, guided participation is a powerful metaphor. In the abbreviated case studies above, our intent has been to demonstrate the range of possibilities mobile learning has for undergraduate and graduate training as well as provide insight into the investments in infrastructure that must be made. In the case of the Mobile Malawi Project, we used the *lack of* traditional landline telephony and network services to leverage the pervasiveness and flexibility of smart phones. Our conclusion is that creative, successful innovations can be devised for mobile learning in higher education where the ideas of guided participation are explicit and valued by members of the discipline and community.

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Author Biographies

Michael A. Evans leads courses and research focusing on the application of human learning theory to the design and development of instructional materials and systems. Current projects include: (a) examining the effects of physical and virtual manipulatives on the mathematical reasoning of elementary students, (b) designing educational simulations and games for middle school students in STEM areas, and (c) developing instructional multimedia for mobile and wireless devices.

Aditya Johri is an assistant professor in the Department of Engineering Education at the Virginia Tech's College of Engineering. Dr. Johri's research examines socio-technical aspects of work and learning with particular emphasis on globalized engineering practices. His current work is funded by NSF and looks at how creativity is organized and supported by digital devises. More information about his work and list of publications can be found at: http://www.enge.vt.edu/People/faculty/Profiles/johri.html