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Mobile Learning: Challenges, Perspectives and Reality

Introduction

The use of information and communication technologies in education and training has undergone several paradigm shifts over the last three decades.[1] Very recently the notions of *e-learning* (learning supported by digital "electronic" tools and media) and *m-learning* (e-learning using mobile devices and wireless transmission) have emerged. Handheld devices are about to become one of the most promising technologies for supporting learning and particularly collaborative learning scenarios. These technologies give the possibility to move away from the stand-alone computer, thus allowing interaction with several devices and making information accessible through a wireless connection to a server. These technologies offer new opportunities for individuals who require mobile computer solutions that other devices cannot provide. Thus, many researchers as well as academic and industrial practitioners are currently exploring the potential of mobile and wireless devices for supporting learning. The challenges are manifold: adapting and appropriating the technology for learning in a way consistent with learning goals and principles, setting up and testing of prototypical applications and scenarios, developing specific software tools and architectures, among others.

As we move into the knowledge society, new interactive technologies provide us with both a challenge and an opportunity. The challenge is to find out how to construct and deploy highly supportive environments, which could be used to provide support for different kind of learning settings. The opportunity is to radically change the ways in which we aid the learning process in order to give students a much higher degree of individual support, and a much more flexible approach to the man-

[1] J. D. Bransford, A. L. Brown and R. R. Cocking (eds.), *How People Learn: Brain, Mind, Experience, and School*, Washington, D.C.: National Academy Press, (1999).

agement of their learning experiences. Bliss et al.[2] argue that the use of these new types of tools and interactive technologies makes possible to develop novel kinds of learning interactions within and across a variety of learning settings. However, it is not so clear how some of the more traditional sites of learning adapt to these changes.

The idea that new technologies will transform learning practices has not yet led to the collaborative ideal. The task of designing effective computer support along with appropriate pedagogy and social practices is simply much more complex than imagined.[3] According to Norris et al.[4] one of the main reasons that the potential of technology has not been realized in primary and secondary classrooms is due to insufficient computer and internet access. They suggest that the introduction of PDAs with wireless capabilities in educational settings may help to overcome this problem.

In the next sections, I will make an attempt to provide a broad perspective with regard to the field of mobile learning by integrating some key ideas from disciplines such as educational research, social science and engineering. My claim is that we need to develop a broad framework, which integrates all these views in order to discuss and to understand the impact of mobile and wireless technologies in education and their implications for the future of learning.

Current Pedagogical Approaches to Learning with Interactive Technologies

Current and emerging trends in education are increasingly moving towards learner-centred approaches.[5] In these, learning becomes an active process of discovery and participation based on self-motivation rather than on more passive acquaintance of facts and rules. The role of the teacher is coming more to be seen as mentor or guide, facilitating and playing an essential role in this process. From this perspective, learning can be considered as a dynamic process in which the learner actively "constructs" new knowledge as he or she is engaged and immersed in a learn-

[2] J. Bliss, R. Säljö and P. Light (eds.), *Learning Sites: Social and Technological Resources for Learning*, Oxford: Pergamon/Elsevier, 1999.

[3] G. Stahl, "Contributions to a Theoretical Framework for CSCL", *Proceedings of CSCL 2002*, Boulder, CO: 2002.

[4] C. Norris, E. Soloway and T. Sullivan, "Examining 25 Years of Technology in Education", *Communications of the ACM*, vol. 45, no. 8 (2002), pp. 15–18.

[5] Bransford et al., *op. cit.*

ing activity. Furthermore, learners will also build understandings through the collaborative construction of an artifact or shareable product. The theory of constructivism is at the core of the movement to shift the center of instruction away from delivery in order to allow the learner to actively direct and choose a personal learning path.

An increasing amount of research has been documenting how new constructivist models may be used to reconceptualize curricula, teaching practices, and learning activities, and to effect significant and rich types of learning gains.[6] Many new constructivist models of learning utilize the affordances of new computational and communications technologies as part of learning environments in which learners engage in challenging problems, collaboration and creation of shared interaction.[7]

Social constructivism, an extension of the constructivist approach, argues that in addition to most knowledge being an interpretation of personal experiences it is also social in nature: knowledge is jointly constructed in interaction. Recent social constructivist perspectives [8] regard learning as enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs, and so on. Social constructivism asserts that a particularly effective way for knowledge-building communities to form and grow is through collaborative activities that involve not just the exchange of information, but the design and construction of meaningful artifacts.

There has also been a growing body of research on authentic and situated learning environments utilizing the problem-based approach to learning.[9] Problem-based learning (PBL) emphasizes solving authentic problems in authentic contexts. It is an approach where students are given a problem, replete with all the complexities typically found in real world situations, and work collaboratively to develop a solution. Problem-based learning provides students an opportunity to develop skills in problem definition and problem solving, to reflect on their own learning,

[6] Cognition and Technology Group at Vanderbilt, *The Jasper Project: Lessons in Curriculum, Instruction, Assessment, and Professional Development,* Mahwah, NJ: Lawrence Erlbaum Associates, 1997.

[7] P. Dillenbourg (ed.), *Collaborative Learning: Cognitive and Computational Approaches*, Oxford: Pergamon, 1999.

[8] D. Jonassen and S. Land, *Theoretical Foundations of Learning Environments,* Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

[9] H. S. Barrows, *How to Design a Problem-Based Curriculum for the Preclinical Years,* New York: Springer-Verlag, 1985.

and develop a deep understanding of the content domain. This approach was developed in the fifties for medical education, and has since been used in various subject areas such as business, law, education, architecture and engineering. Most recently, there is a growing interest among educators to use problem-based learning in the K-12 setting, and a growing need for problem-based educational software to facilitate the development of higher order thinking skills via technology.

An underlying assumption of all these approaches is that most effective and meaningful uses of interactive technologies to support learning will not take place if technologies are used in traditional ways. According to Jonassen et al.,[10] meaningful learning will take place when these technologies allow learners to be engaged in the following activities:

- Knowledge construction
- Conversation
- Articulation
- Collaboration
- Authenticity
- Reflection

Wireless and Mobile Technologies in Education

In the past decade, the internet has spawned many innovations and services that stem from its interactive character. There are numerous indications that the ongoing process of adding mobility to interactivity will transform the role of the internet and pave the way for yet another set of innovations and services. The convergence of computing and communication is a process that is about to turn phones and mobile terminals into powerful multimedia units. The XML-based Synchronized Multimedia Integration Language (SMIL), for instance, is devised for the distribution of sophisticated multimedia content in a variety of devices, ranging from stand-alone computers to cellular phones.

Thanks to the convergence of telecommunications and data communication, future computer applications will rely on seamless wireless networking, and will thus be inherently mobile. This latest trend is now observable and a clear example is the convergence between two technologies that had developed separately during most of the nineties: wireless communication devices (pagers, mobile phones) and handheld de-

[10] D. Jonassen, K. Peck and B. Wilson, *Learning with Technology: A Constructivist Perspective,* Upper Saddle River, NJ: Prentice Hall, 1999.

vices (personal digital assistants, PDAs). Recently, a number of mobile phones and other wireless devices with PDA capabilities have been introduced; conversely, more and more handheld devices now come equipped with wireless capabilities.

Tablet PC is one of the major latest initiatives of computer's manufacturers. Task-specific tablet computers have existed before, but now a number of software developer houses are providing software-development kits (SDK) with general functionality for pen-based applications. It is possible to imagine that tablet PCs will replace laptop devices in the near future because of more natural interfaces and a more desirable form factor. The Tablet PC shares many qualities of the handheld and differs from it in its increased computational power, the larger and higher resolution display/touch surface.

All these new forms of interactive multimedia and communication offer new possibilities as to the way we learn, think, and communicate. The combination of handheld computing and wireless communication suggests enormous potential for education, especially given how familiar most young students already are with these technologies. However, and in spite of the widespread acceptance of the technology among teenagers and young people, mobile and wireless technologies represent a low percentage of those technologies used in the classrooms during lectures/ /educational activities. These devices are seldom used and in many cases their use in the classroom is forbidden.

To date most educational applications have been connected to the desktop, as they have relied on the processing power of that form factor. As we move these applications from the desktop to more ubiquitous and increasingly powerful portable devices, we could simply port existing tools to new emerging platforms. This change in form factor alone would provide advantages in price and accessibility to students. But the move from the desktop to the handheld computer provides other potential advantages, which make this an especially attractive platform for supporting learning. Klopfer et al.[11] have enumerated a number of features that make handhelds interesting for education. Those features, which are consistent with the pedagogical ideas presented in the previous section, are described below:

Portability: One can take the computer to different sites and move

[11] E. Klopfer, K. Squire and H. Jenkins, "Environmental Detectives: PDAs as a Window into a Virtual Simulated World", in M. Milrad, U. Hoppe, and Kinshuk (eds.), *Wireless and Mobile Technologies in Education*, Los Alamitos, CA: IEEE Computer Society, 2002, pp. 95–98.

around within a site. Mobile and wireless applications enable ubiquitous learning. The bounds of the classroom can now be extended to the limits of wireless networks.

Social interactivity: As mobile and wireless technologies enable peer-to-peer communication, students will have a way to interact directly with one another. Students can exchange data and collaborate with other people face to face.

Individuality: Can provide unique scaffolding that is customized to the individual's path of investigation.

Context sensitivity: Digital systems provide the ability to automatically log and aggregate usage, which can be used to design collaborative filtering systems, predictive user interfaces, etc. in the design of mobile applications.

Connectivity: Can connect handhelds to data collection devices, other handhelds, and to a common network that creates a true-shared environment

Merging digital and physical realms: In stationary settings, the digital and physical worlds are more or less separated (users "look into" and manipulate the digital world on the computer screen). In contrast, in mobile systems these realms may be combined. Sensors, smart rooms and ambient environments capture real-world information of users and devices and represent it in a format that is usable in the digital realm. Geographical information systems (GIS) are building on these and other properties to create many other new and innovative applications.

Educational Application of Mobile Devices

One of the major challenges for educational technologists and researchers is to find useful ways to implement and evaluate emergent technologies and innovative pedagogical ideas in educational settings. Gay et al.[12] have defined the term "mobility hierarchy" that refers to four different kinds of objectives motivating the use of educational application of mobile devices. These four categories range from the simple applications providing tools to achieve the objectives of "productivity" (calendars, contacts, schedule, etc.), as they call it level 1, to the most complex applications, which provide tools to achieve multiple objectives called "communication & collaboration" or level 4. An application at

[12] R. Gay, R. Rieger and T. Bennington, "Using Mobile Computing to Enhance Field Study", in Koschman, Hall and Myake (eds.), *CSCL 2: Carrying Forward the Conversation*, Lawrence Erlbaum, Mahwah: NJ: 2002, pp. 507–528.

this level will enable collaborative work and also will provide features for collecting and analyzing data. According to Pinkwart et al.[13] the currently available educational applications on PDAs can be categorized according to two main types of usage:

a) The PDA serving as an interface to a "main" desktop program to extend the use of the desktop application for specific scenarios. Here, the mobile device may in the extreme case just serve as a front end, e.g. for outdoor data input.

b) A stand-alone application running on the PDA, with or without connection to a central desktop application. This approach includes also several mobile applications allowing collaboration via direct communication between the devices.

Examples of the first category are "ImageMap" from SRI International or the "museum guide" of CILT.[14] In the case of "ImageMap", students who receive an image on their mobile device and have to answer a given question to it using annotation techniques use the PDA. Having done so, they send their annotations back to a server where all the different comments are gathered and displayed on a public screen, allowing teacher and students to discuss the answers. Similar to the case of "ImageMap", the mobile application "museum guide" is also essentially an interface for communication with a central server. It is used primarily for retrieving data and displaying information about a museum. The current location of a user can be detected and is considered for offering location-based information to the user. Applications and concepts illustrating the second category include "Geney" by EDGE Lab / CS Division and "PiCoMap" from the hi-ce group.[15] The goal of "Geney" is to collaboratively "engineer" a fish with a particular set of characteristics under restrictions coming from genetic rules. The students take different roles: one of them acts as a "manager" whose fish will be paired with one fish collaboratively constructed by the other students. During

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[13] N. Pinkwart, Christian Schäfer, U. Hoppe, M. Milrad and J. Perez, "Lightweight Extensions of Collaborative Modeling Systems for Synchronous Use on PDAs", *JCAL: Journal of Computer Assisted Learning*, Special Issue on "Mobile and Wireless Technologies in Education", Fall 2003 (to appear).

[14] J. Roschelle and R. Pea, "A walk on the WILD side: How Wireless Handhelds may Change CSCL", *Proceedings of CSCL 2002* (Conference on Computer Support for Collaborative Learning), Boulder, January 2002.

[15] K. Luchini, Ch. Quintana, M. Curtis, R. Murphy, J. Krajcik, E. Soloway and D. Suthers, "Using Handhelds to Support Collaborative Learning", in Stahl (ed.), *Proceedings of CSCL 2002*, Hillsdale, NJ: Lawrence Erlbaum, 2002, pp. 704–705.

a so-called "what-if" mode, the view on the mobile applications differs according to the student's role: the manager sees a condensed overview whereas the other participants have a more detailed but restricted view of resulting characteristics. So, the students have to combine perspectives and collaborate to achieve optimal results.

With the "PiCoMap" application, students can illustrate a specific given problem using a graphical representation consisting of nodes with text input, and directed links. Having done so, they can exchange their developed models pair-wise. Afterwards, they annotate the ideas of the co-learner. The aim of this system is to lead students to a discussion about their different views and, finally, to a revision of their original ideas taking into account the result of the co-learners. Most of the mentioned tools use infrared connection as the channel to exchange information between mobile devices. The disadvantages of this approach are:

- it does not directly support continuous co-construction in shared workspaces (instead, only repeated "one-time" data upload or download is facilitated);
- it is (at least currently) quite restricted in terms of bandwidth.

While the second aspect is of limited relevance in usually not overcomplex pedagogical scenarios (and might soon be overcome), the first disadvantage really restricts the spectrum of potential collaborative processes. The use of wireless LAN connections can solve this problem and thus offer more flexible ways to support collaborative work. Here, completely synchronized mobile applications are enabled for a variety of collaborative scenarios.

However, for applications built upon these technologies to be successful for children and the education community, research needs to understand what are the special needs of learners and instructors, as well as the kinds of collaboration, social interactions, guidance, and activities that need to be supported for learning. Moreover, the requirements for mobile learning applications will be very different from the stationary (primarily desktop-based) setting that has until recently been the dominating one in Human Computer Interaction.[16] In the next section I describe some of our research efforts underway within the field of wireless and mobile technologies in education.

[16] A. Marcus and E. Chen, "Designing the PDA of the Future", *Interactions,* vol. 9, New York, NY: ACM Press, 2002, pp. 34–44.

Research Perspectives

We at *CeLeKT* have recently initiated a research effort to explore new design approaches and innovative uses of wireless and mobile technologies in a variety of collaborative educational settings. Our vision is not simply to provide novel mobile and wireless computational tools, but rather to explore new and varied educational activities that become available while applying innovative approaches for designing new technology to support learning.

Technical innovation in these areas is particularly characterized by using new types of interaction devices and new communication technologies such as hand-held and tablet computers, physical interfaces with smart interactive objects and wireless networks in ubiquitous computing environments. The envisaged and partially already existing research products are software components and architectures, which facilitate human–human communication in cooperative work scenarios as well as interactive and collaborative learning activities such as model building in groups. Our work is motivated by the following guiding questions:

1. *How can the use of wireless and mobile technologies provide new opportunities for learning and collaboration? (Design/Usability aspects.)*
2. *What might be an ideal configuration of a wireless computer for learning?*
3. *How should learning theories be incorporated into the design of the desired architecture?*
4. *How should ubiquitous computers and the contexts they mediate be designed to ensure the needs of learners are met?*
5. *What features and capabilities should the mobile computing systems provide for different learning and teaching activities?*
6. *Which evaluation methodologies are suitable for assessing the value added of new technologies in learning and work settings?*

From an engineering/design perspective, we base our technical developments on standard platforms and environments. Particularly, we use Java and Java extensions (RMI, JINI, Java Media Framework) for the processing mechanisms and XML (including SMIL, SVG, etc.) for data structuring, storage and data exchange. The big challenges still lie in the integration not only between software components in distributed environments, but also in the combination of software with new hardware and peripherals as well as the support for delivery on different types of devices. In this spirit, a special focus of our work is set on exploring and exploiting the potential of mobile/hand-held and wireless devices.

Over the last decades, we have seen qualitative changes in Information and Communication Technologies (ICT) at a very rapid pace. The paradigm of stand-alone personal computers that was introduced in the early 1980s as a successor of mainframes and timesharing systems, has been replaced by the networked computing paradigm. Now, there are indications from within the ICT community that future developments may no longer be centred around the explicit and dominant role of the computer. The new view of ICT is most sharply crystallized in the notion of the "Disappearing Computer". This particular topic is now also the theme of an ongoing European research initiative (http://www.disappearing-computer.net) at the crossroads of computer science, social sciences and innovative design.

Some years ago, the term ubiquitous computing[17] was defined as an attempt to create and design more "transparent" technologies to break away from the traditional desktop activity and moving computational power to the region of activity where the user is engaged. Weiser and Brown refer to designing computational objects in our surrounding//environment that become an integral and transparent part of our lives. These objects also are equipped with network capabilities and they help us to mediate our activities with or without awareness of their role. Donald Norman has propagated a similar vision in his book the *The Invisible Computer*.[18]

Weiser and Brown claim that such forms of ubiquitous computing will lead to a new age of "calm technology" which is characterized by having multiple computerized services around us in an implicit and unobtrusive way. This technology will no longer define the focus of our attention. Even the current notion of a "user" would be misleading if this vision were completely materialized. The point would no longer be the human–computer relationship but the availability of certain services located in the physical (and virtual) environment. Already today, we "see" multiple processors being invisibly embedded in many technical devices such as automobiles, dishwashers and other equipment in workplaces and homes. This should not be confounded with invisible computing in the envisaged sense. In these other applications, computers

[17] M. Weiser and J. S. Brown, "The Coming Age of Calm Technology", in P. J. Denning and R. M. Metcalfe (eds.), *Beyond Calculation – The Next Fifty Years of Computing*, New York: Copernicus (Springer), 1997.

[18] D. A. Norman, *The Invisible Computer*, Cambridge, MA: MIT Press, 1998.

essentially serve as controllers and regulators of processes within a device or between technical devices. The innovation that we are interested in has to do with information processing in which "the human is in the loop", i.e. with *interactive and collaborative* applications. Here, "explicit computing" is still predominant.

An early approach of how to adapt ubiquitous computing technology to the classroom has been described in Hoppe et al.[19] It featured a combination of new hardware devices, namely big interactive screens ("LiveBoards") and tablet displays for free-hand input, with a networked classroom environment in which typical patterns of information exchange in a classroom were supported by specific groupware functions. One of the basic ideas was the provision "electronic worksheets" which could be distributed and collected by the teacher and which could be used in synchronous cooperative mode between students or be shared through the LiveBoard. This type of scenario was called a "computer-integrated classroom" (CiC), reflecting the central idea of using computer and communication technologies to support interaction and information exchange in a face-to-face classroom. The CiC idea was put into practice in schools in the European long term research project "Networked Interactive Media In Schools" (NIMIS, 1998-2000).[20]

In this perspective, we pursue the following concrete projects:

- Development of ubiquitous computing techniques for informal information sharing (background technologies such as "electronic pinboards" with access through SMS, PDAs or tablet computers as input devices, communicating notepads between collaborators)
- Integration of location-awareness with other communication services, potentially on the physical level in order to support spatially contextualized information services and knowledge exchange

[19] H. U. Hoppe, N. Baloian, J. Zhao, "Computer Support for Teacher-Centered Classroom Interaction", *Proceedings of ICCE '93* (International Conference on Computers in Education), Taipeh, Taiwan, December 1993.

[20] Cf. H. U. Hoppe, A. Lingnau, I. Machado, A. Paiva, R. Prada and F. Tewissen, "Supporting Collaborative Activities in Computer-Integrated Classrooms – the NIMIS Approach", in Salgado, Antunes and Costa (eds.), *Proceedings of CRIWG 2000*, IEEE Press, 2000, pp. 94–101.

Computer Support for Collaborative Learning

Computer support for collaborative learning (CSCL) is the label for a rapidly growing community of researchers with a multidisciplinary background, which includes computer science, cognitive science, education as well as sociology and social psychology. Typical application fields are:

- Distance education and "virtual learning"
- Social aspects of learning communities
- Organizational and tool support for intellectual teamwork and knowledge management
- Development and evaluation of classroom collaboration tools
- Development and evaluation of collaborative tools for learning in the workplace

Within this broad framework of CSCL, our specific orientation will be focused on scenarios using mobile and wireless technologies. If these new mobile technologies are used to support active and/or collaborative forms of learning, the expected gain or added value is typically defined quite differently: Handheld computing devices allow for exploratory activities not bound to a special location, for example field trips, without losing the potential of taking electronic notes and retrieving information of various types.[21] Such notes, ranging from data collections and digital images to handwritten annotations, can be easily exchanged and downloaded. If combined with wireless transmission, these activities can be continuously monitored and coordinated between places. But even in classrooms and training settings with more or less fixed locations, the use of mobile and wireless technologies may lead to substantial changes in that small hand-held or embedded devices are no longer dominating the interaction in the same way as an "explicit" computer does. This can help us to bring the technology to the background and to set the focus more on inter-personal relations and on the task at hand.[22]

Our research efforts in this direction are oriented towards the exploration of new design approaches and innovative uses of wireless and mobile technologies in a variety of collaborative educational settings. These

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[21] Gay et al., *op. cit.*

[22] J. Roschelle, C. Patton and R. Pea, "To Unlock the Learning Value of Wireless Mobile Devices, Understand Coupling", in M. Milrad, U. Hoppe, and Kinshuk (eds.), *Wireless and Mobile Technologies in Education*, Los Alamitos, CA: IEEE Computer Society, 2002, pp. 51–60.

efforts aim at investigating the challenges of designing and using mobile technology for:

- providing learners with new mobile computational tools to explore and share their knowledge with other peers;
- providing teachers with new communication channels to visualize students' ideas;
- fostering collaboration among students and among students and teachers.

The following concrete activities are in-line with this perspective:

- The use of new mobile devices to support academic study groups as in the C-Notes application[23]
- The use of wireless devices for data collection and visualisation in experimental settings in science museums[24]

Conclusions

As presented in this paper, wireless and mobile computing has the potential of enabling learners to share information, coordinate their tasks and conduct a number of educational activities in new ways. Efforts in this direction and applications of mobile and wireless technologies in education have been in use for almost 10 years.[25] However, due to a number of social, economical and educational factors, these technologies are just now being introduced to different educational arenas.

It is essential to remember that the introduction of new technological tools takes place into existing social environments having their patterns of interaction, own culture. These new tools, then, should be interpreted and used accordingly, but they can also have a major impact transform-

[23] M. Milrad, J. Perez and U. Hoppe, "C-Notes: Designing a Mobile and Wireless Application to Support Collaborative Knowledge Building", in M. Milrad, U. Hoppe, and Kinshuk (eds.), *Wireless and Mobile Technologies in Education*, Los Alamitos, CA: IEEE Computer Society, 2002, pp. 117–120.

[24] J. Gottdenker, M. Milrad, A. Wichmann, D. Jonassen, J. Strobel and J. Perez, "Exploring New Ways for Supporting Scientific Inquiry: Hands-On High-Tech Science Learning", in preparation.

[25] C. Wayne, "Wireless Coyote: A Computer-Supported Field Trip", *Communications of the ACM*, vol. 36, no. 5 (1993), Special issue on technology in K–12 education, New York, NY: ACM Press, pp. 57–59.

ing those cultures and practices. The mediation of mobile and wireless technologies and applications challenges traditional distinctions between "new learning environments" taking place anywhere/anytime to the notion of learning in the classroom, and it generates new learning and teaching activities and opportunities.

Such an understanding of the role of technology differs significantly from earlier suggestions to conceive computers as "dialogue partners". We see this new orientation as a consequence based on lessons learned from the limited success of past technology-centered approaches. A criticism of such earlier approaches to learning does indeed not exclude the use of the newest technology in the most creative and innovative ways. The point is that the learning environment, including such aspects as roles of learners and teachers, types of activities, and physical settings, should not be adapted to the available technology but instead, the technology should be designed for and adapted to the learning needs. And our hope is that better technology should adapt and serve better.

As we continue to conduct more research in this new field and to collect more empirical data, we will gain a richer understanding of the potential using mobile and wireless technologies for improving the design of technology-rich contexts for supporting learning and teaching. I would like to encourage all our colleagues in this area of research to continue this exploration so that we may ground theoretical conjectures regarding the potential of these contexts in empirical findings. More broadly, I hope that further research will help us to develop a richer theoretical framework for understanding the role of these new kinds of technologies and their implications for improving the level of education.