

Avraamidou, L. (2008). Prospects for the use of mobile technologies in science education. *AACE Journal*, 16(3), 347-365.

Prospects for the Use of Mobile Technologies in Science Education

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During the past few years there have been great strides in the advancement of technology with the rise of mobile devices leading to an era characterized by the instant access to and mobility of information. Mobile technologies have more recently been used in a variety of educational settings for a variety of purposes and educational goals. Nevertheless, while the claims about the positive impact of the use of mobile technologies in different aspects of education are compelling, data on how these technologies support, for example, the understanding of complex concepts or the development of learning skills that enable students to think critically and problem-solve, are limited. This theoretical article contends that missing, remains a detailed characterization of the accounts and the processes through which mobile technologies mediate learning, and proposes that future research in science education is directed towards: (a) exemplifying the theoretical aspects and the characteristics of design frameworks associated with mobile learning; (b) characterizing rich and complex pedagogical practices that use mobile devices; and (c) sketching the details of the processes by which students come to know through engagement in activities that use mobile technologies.

During the past few years there have been tremendous strides in the advancement of technology with the rise of mobile devices leading to an era characterized by the instant access to and mobility of information. Mobile

devices such as cellular phones, personal audio players, personal digital assistants, and portable computers have reshaped and redefined the ways in which information is constructed, accessed, and communicated among individuals and societies. As these mobile devices converge and wireless connectivity becomes more prevalent, remarkable technical capabilities are offered and profound innovative learning possibilities are now made feasible. As Kukulska-Hulme (2005) noted:

We are beginning to see significant adoption of these technologies in further and higher education, in schools and the community, and in training and updating. They are having an impact on teaching, learning, and on the connections between formal and informal learning, work and leisure. (p. 1)

According to a review about the use mobile technologies in education, done at the Futurelab (Naismith, Lonsdale, Vavoula, & Sharples, 2005) mobile wireless devices can be used by school teachers for managing their schedules, reviewing student marks, accessing central school data, attendance reporting, and providing course material. Students as well can use mobile wireless devices for collecting, organizing, and exchanging data quickly. More recently, mobile devices have gained popularity within higher education settings as well. As a matter of fact, the development of mobile devices has generated a considerable amount of interest among both academics and practitioners given that many institutions now offer courses using mobile technologies as an alternative approach to teaching and learning (Kim, Mims, & Holmes, 2006).

However, regardless the widespread use of mobile technologies in educational settings through the design and implementation of technology-enhanced curriculum materials, missing remains a theoretical analysis of the role of mobile technologies in science education in particular, and a comprehensive synthesis of research findings about mobile learning. This article aims to address this gap by examining the merits of the proposition that mobile devices are used in educational settings and particularly in support of science learning. In attempting to do so, this article provides first, a set of theoretical perspectives on the intertwined nature of science, technology, and society. Next, the article provides a review of selected research literature with the aim of understanding how developments in mobile and ubiquitous computing can support the design of innovative learning environments. More specifically, the goals of this article are to: (a) examine the relationship

between science and technology education in an attempt to address a perceived disjuncture between school science and the demands and challenges of the technologically oriented societies; (b) summarize evidence from research studies regarding the use of mobile technologies in education with special attention to science education; and (c) propose future research directions associated with the use of mobile technologies in education.

SCIENCE AND TECHNOLOGY EDUCATION: A HISTORICAL REVIEW

Even though the construction of artifacts by humans goes back a thousand years, the questions of what constitutes technology, technology education, understandings of technology, how technology relates to science literacy and how it affects society are relatively recent, dating early in the 20th century. In a historical review of the transformations in formal technology education, Cajas (2001) described three main movements that characterize tendencies of technology education related to three different perceptions of technology as artifact, as knowledge and as social practice. The manual arts education movement identified technology mostly with artifacts and included courses such as drawing, woodworking, metalworking and printing and focused on the teaching skills relevant to the workplace. Following this movement initiated early in the 20th century, the industrial arts education dominated technology education. Industrial arts education emphasized more sophisticated technological knowledge, which “moved the conception of technology from artifact to knowledge and skills, in particular the knowledge and skills needed to participate in a more technical society” (p. 717).

It was not until the 1970s that the technology education and science education routes intersected with the highlight of the Science, Technology, and Society (STS) movement by science educators who suggested that the science curriculum should be organized around societal and technological issues (Aikenhead, 1985; DeBoer, 1991). This STS movement proposed a new conceptualization of science education built on the premise that science is socially structured as much as science influences the structure of society (Kuhn, 1962). According to Hart and Robottom (1990), the STS proposals “appear to have the potential to transform school science into a more meaningful approach and epistemologically coherent form of science education” (p. 584).

This article is inspired by the potentials of such an approach and borrows from Cajás' (2001) wider perspective of technology as artifact, knowledge, and social practice, which goes beyond an understanding of technology either as artifacts or computer skills and is used to embrace both technological and science literacy and exemplify the relationship between technology and education. A review of global reform documents indicates a parallelism between science education and technology and points to the intertwined nature of scientific literacy and instructional design. For instance, in the *National Science Education Standards* (National Research Council, 1996) scientific literacy is used to include one being technologically informed. According to Lewis (2006) technology design and scientific inquiry are conceptual parallels given the fact that the connection between science and technology in contemporary times is inescapable. Likewise, Benenson (2001) stated that,

The goal of systemic improvement of science education is motivated in large part by the demands of our society for technical literacy and expertise. Most people are aware of the scientific expertise primarily through its technological by-products. (p. 730)

Scientific and technological literacy are at the heart of the account of this article aiming to explore new directions in science education associated with the use of mobile technologies, in light of the demands and challenges of technologically oriented societies. Built on the premise that science and technology are inseparable in society, this article proceeds to explore how recent advancements in technology have impacted the way learning is conceptualized and defined.

A "MOBILE" CONCEPTUALIZATION OF LEARNING

Technology tools have reshaped the way teaching and learning is viewed during the past few years as they provide access to information, the means to engage and manipulate resources and the opportunities for communication of ideas and collaborations at both individual and institutional level. In fact, computer software applications have been extensively used in a whole plethora of ways with students of different ages because of their potential to support learning. Jonassen (1996) referred to computer software applications

as “mindtools,” which have the potential to engage learners in a variety of critical, creative, and complex thinking, such as evaluating, analyzing, connecting, elaborating, synthesizing, imagining, designing, problem solving, and decision making. In a paper arguing about the use of current learning technologies broadly in schools, Fishman, Soloway, Krajcik, Marx, and Blumenfeld (2001), referred to *tools for thinking*, that are used to promote collaboration, expression of ideas and discourse among students, tools for modelling cause and effect relationships, tools that scaffold complex investigations, and tools that enable students to visualize complex scientific phenomena.

Such tools are today encompassed in mobile devices suggesting the need for a reconceptualization of learning through the lens of what is commonly used to mean learning on the move, termed as *mobile learning*. As the Latin origins (*mobilis*) of the term suggests, mobile learning refers to learning that is *able to move freely*. The term has its origins on an essential aspect of mobile technologies: mobility, which refers to continuous use without limitation of time and location. As defined by Quinn (2000), “mobile learning is learning through mobile computational devices.” Seppala and Alamaki (2003) summarized the distinctive features of mobile learning in that it takes place at any location, and not necessarily in the classroom, and that it enables learners to enter an information network by using a portable learning device and a wireless network. A question that arises from a theoretical exploration of mobile learning is whether there is a need to theorize about mobile learning in order to take into account its unique characteristics and essentially construct a theory of mobile learning. Sharples, Taylor and Vavoula (2005) argued that, “there is a need to reconceptualise learning for the mobile age, to recognise the essential role of mobility and communication in the process of learning, and also to indicate the importance of context in establishing meaning” (p. 1). The theoretical approach of this article is that mobile learning can be generally defined under the umbrella of sociocultural theories of learning and particularly the theory of situated cognition, which suggests that “activity and perception are importantly and epistemologically prior—at a nonconceptual level-to conceptualization and that it is on them that more attention needs to be focused” (Brown, Collins, & Duguid, 2001, p. 48). This theoretical approach to mobile learning places emphasis on the contextual interactions among individuals and tools, a process of enculturation into a learning situation. Nevertheless, in agreement with Sharples, Taylor, and Vavoula (2005), this article suggests that special attention should be paid to the unique characteristics of mobile

learning in that it can happen at any physical location at anytime and that it is mediated by mobile technology tools. As Kukulska-Hulme (2005) pointed out, “mobile learning has a range of attributes that might contribute to its definition: it can be spontaneous, personal, informal, contextual, portable, ubiquitous, and pervasive” (p. 2). Examples of mobile learning situations with special emphasis on handheld computers and how those are used to support learning are described in the section that follows.

THE USE OF MOBILE TECHNOLOGIES IN EDUCATION

Recent advances in technology have led to the design of even more advanced mobile devices, which are networked wirelessly. Some examples of such devices are the tablet PCS, the mobile phones, the personal digital assistants (PDAs), the handheld computers, the pocket-PCs, and the Intelligent Active Badges. These devices have provided opportunities for instant access to information and enabled instant communications, and have inevitably impacted human relationships and social structures. According to Naismith et al. (2005), “mobile technologies are becoming more embedded, ubiquitous and networked, with enhanced capabilities for rich social interactions, context awareness and internet connectivity” (p. 6). These technologies today are called “mobile wireless devices” and they have an integrated wireless card that enables short-range wireless voice and data communications. Unlike wired technology tools, such as wired personal computers, these devices use a wireless network interface card (WNIC) to connect to a network that uses a low radio frequency.

A review of the literature indicates that the use of mobile wireless devices has been one of the main trends in education the past few years (McKenzie, 2001; McGhee & Kozma, 2001; Kukulska-Hulme, 2005). Researchers have argued that these technologies have the potential to improve efficiency and effectiveness in teaching and learning (Dubendorf, 2003) and to challenge the essence of face-to-face teaching and learning (Kukulska-Hulme, 2005). In examining the benefits of mobile wireless technologies in education Kim et al. (2006) summarized those in the following: (a) mobility, which is associated with the advantage of accessing information anytime, anywhere; (b) information management capacity, which is associated with the digitization of information and electronic-based management; and (c) beaming capability which allows the sharing of files instantly and in real-time. Of

great interest among researchers has been the use of one particular type of mobile technologies, the handheld computers which is also the point of interest in this article.

Handheld computers are those portable computational tools that are small enough to be held in one's hand and combine functionalities of computing, telephone, Internet, and network (Webopedia Computer Dictionary). Examples of such technologies are the Personal Digital Assistants (PDAs), handheld computers, and wearable computers. Handheld technologies are unobtrusive computing devices that accompany the user and provide assistance in a variety of situations and for a wide range of tasks (Schmidt & Beigl, 1998). These technologies were originally designed as personal organizers and electronic diaries, but most can now perform a variety of other functions similar to ones that desktop machines can do. According to Trinder (2005), "on many models, you can display documents, write notes, do word searches, play games, record your voice, listen to sound files, view pictures and video clips, and take photographs" (p. 8).

What is of value about the use of these technologies for education is that tools that first existed only on expensive desktop machines are now available on inexpensive handheld units (Soloway, Norris, Blumenfeld, Fishman, & Marx, 2001). Examples of such tools are representation tools, communication tools, graphing calculators and tools for mapping concepts, running simulations, gathering data, and so forth. Certain characteristics of handhelds in particular, are seen as positive indicators of potential effective use in education. These characteristics are associated with portability given their small size, the cost advantage and longer battery life over laptops, and the ease of synchronization and sharing of data through infrared. The issue of affordability is, in fact, one of the main advantages of handhelds, when one considers that, for example, a color Palm operating system device with a keyboard and some software is about \$300. At the same time, handhelds are simple to maintain and generally they do not require technical support.

Other arguments favoring the use of handheld computers in education, according to Zurita and Nussbaum (2004), suggest that handhelds "support constructivist educational activities through collaborative groups, increasing motivation, promoting interactive learning, developing cognitive skills and facilitating the control of the learning process and its relationship with the real world" (p. 235). It is such arguments that led researchers to explore the use of mobile technologies and specifically handheld computers (i.e.,

small, personal, portable computers with touch screens) in support of learning with students of different ages within a variety of learning contexts and situations.

Rochelle (2003) summarized three main classroom applications of wireless devices that have received the most prolonged research attention: (a) classroom response systems; (b) participatory simulations; and (c) collaborative data gathering. A *classroom response system* provides a teacher with the possibility to instantly collect students' responses on posed questions. Given that each student holds one handheld computer they can send their response anonymously and then the system aggregates the students' responses and presents them in a coherent form, such as a histogram. Such possibilities have pedagogical implications considering how teachers can monitor and assess student learning. The second type of classroom applications, as described by Rochelle, are the *participatory simulations*, which "use the availability of a separate device for each student and the capability of simple data exchanges among neighboring students" (p. 5). These simulations are called participatory since are distributed within the class with the use of mobile devices and they enable students to model scientific phenomena, in the sense that they act as agents in these models. The third type of classroom applications associated with handhelds has a history in science education. This type of application is called *collaborative data gathering* and uses Probeware to gather, organize and graph data from experiments. A popular scenario used in this type of application is the water quality evaluation (Vahey & Crawford, 2002), where students use their handhelds and probes to take measurements along different points of a stream. Other popular scenarios used in different applications and occurring in a variety of formal and informal learning contexts are discussed next through a review of the literature on the use of handheld computers in education.

THE USE OF HANDHELD COMPUTERS IN SCIENCE EDUCATION

Handheld computers have been used in a variety of educational settings and for the purpose of achieving a wide range of goals. For example, handhelds have been used in informal settings such as science centers (Bannasch, 1999) and Museums (Kirk, 2001; Spasojevic & Kindberg, 2001) for the purpose of mediating visitors' experiences. Moreover, handhelds enjoyed

great use during field trips (Grant, 1993) particularly for the purpose of data collection (Hsi, 2000; Hsi, Collison, & Staudt, 2000) and in combination with probewares in science classrooms (Bannasch & Tinker, 2002). Other applications of handhelds include constructing concept maps (Luchini et al., 2002), monitoring habitats and identifying species (Parr, Jones, & Songer, 2004), and supporting classroom assessment in science (Yarnall, Shechtamn, & Penuel, 2006). Regardless the fact that handhelds have been used in many different ways, for different purposes and with students and teachers of different ages, research findings generally indicate positive outcomes associated with their use within school settings, outdoors settings, and museum settings.

Handhelds in School Settings

A large-scale study carried out by SRI international, under contract from Palm Inc. looked into the advantages of using handheld computers in the classroom within the context of different subjects. This study involved 102 teachers who received grants from the Palm Education Pioneers (PEP) program and provided each of their students with one handheld computer. Advantages in using handheld computers in the classroom, as indicated in the report, included the integration of technology throughout the school day and facilitated self-paced learning and independent work. More specifically, 84% of the teachers stated that using handhelds increased students' self-directedness in learning, about 77% said that students showed initiative in using handhelds for learning, and among projects where students were allowed to take handhelds home, approximately 75% of teachers reported an increase in homework completion.

Other studies have dealt with the use of handhelds specifically within the context of school science in a variety of learning situations and for achieving different goals. A significant body of work comes from the Center of Highly Interactive Classrooms at the University of Michigan, where a group of educators, computer scientists, psychologists, learning specialists, and scientists are involved in the design of inquiry-based curricula and the Center for Innovative Learning Technologies (CILT) Ubiquitous Computing Project at the Concord Consortium.

In a study about the feasibility and educational use of probeware and associated instructional materials in middle school science education,

Metcalf and Tinker (2003) developed two middle school science curriculum units, six low-cost probes and associated software and curriculum. These materials were tested by 30 teachers in the first year and by 8 teachers in a follow-up study in the second year. With the use of inquiry-based learning strategies, the materials were used to engage students in investigations that covered two content areas of physical science: Force and Motion and Energy Transformations. Pre/posttests, surveys and interviews, and classroom observations were done by the researchers to evaluate student learning and the effectiveness of the components of the project. Analysis of these data illustrated that student learning was enhanced as they developed understanding about science concepts and confronted misconceptions and teachers found that the probes and handhelds were very useful and they were eager to use the materials again.

Handhelds in Outdoors Studies

Handhelds have also been used outside of the classroom and specifically in outdoor studies (Hsi, 2000; Staudt, 1999). An example comes out of a pilot study with a second grade and a fifth grade classroom by Staudt who examined whether and how the use of handhelds and probewares supported students in note taking and data collection. The students engaged in different kinds of investigations such as taking the temperature of the air, the temperature down a drainage hold and a shallow pond near their school. The findings of this study showed that both the second and fifth grade students that participated in this study were undaunted by the technology as they easily moved between note taking and data collection. As Staudt stated, “the handheld computers gave students the opportunity to connect their questions and investigations to the data while in the field.” This is important given that it provides students with opportunities to engage in practices such as collecting *authentic* data from the field, a process which, models in some sense the work that is done by scientists.

Handhelds in Museum Settings

Handheld devices have also been used in informal learning contexts such as Museums and Science Centers to mediator the visitors’ experiences (Hsi,

2002; Kirk, 2001; Spasojevic & Kindberg, 2001). Hsi reported the findings of a research project called the *Electronic Guidebook*, whose aims were to understand how the introduction of wireless technologies changes and augments user experiences at the Exploratorium, in San Francisco. According to Hsi, with the use of an Electronic Guidebook, visitors had the opportunity to access additional information about exhibits, to engage in measurement, data collection, and other experimentation related to the phenomena demonstrated by the exhibits with the use of networked handheld devices, to engage in communication with others, and to capture their museum experience through online records. In a descriptive study of fifteen users (including teachers, staff explainers and visitors) in the context of the Electronic Guidebook, Hsi analyzed data from field observations, interviews and log files to explore the ways in which wireless handheld resources could be useful for different users in the context of a museum center. The findings of this study indicated that the majority of users reported that the handheld resources motivated and prompted new ways to interact with the exhibit and supported further thinking about ideas that were demonstrated in the mobile web content.

As it becomes apparent from this review of selected literature on the use of handheld computers in education, evidence suggests that there is great profit in the use of handhelds in education. Few studies, however, have documented the great complexity of the ways in which handheld computers support meaningful learning. While the claims about the positive impact of the use of handhelds in different aspects of teaching are compelling, data on how handhelds support, for example, the understanding of complex science concepts or the development of learning skills that enable students to think critically and problem-solve, are limited. In attempting to address this gap in the literature, the next section is devoted to sketching the details of the design of a qualitative research program—*HandLearn* aimed at investigating the use of handheld computers within the context of elementary school science. Providing extended accounts of data analysis and research findings of the program is beyond the scope of this article, therefore the emphasis of the next section is on the design-aspects and the nature of the instructional activities and research questions of the program.

HANDLEARN

The aim of HandLearn¹ is to investigate through a qualitative case study of a 6th grade classroom the use of handheld technologies as a means to support inquiry-based science investigations. More specifically, the project aims to: (a) develop curriculum material based on sociocultural theories of learning (Rogoff, 2003) and informed by perspectives on the nature of science (Abd-El-Khalick, Bell, & Lederman, 1998); (b) to investigate the role of handheld devices in teaching and learning in science; and (c) to produce material for teacher professional development. The context of Handlearn combines formal (i.e., classroom) and informal (i.e., park) learning environments. For the purposes of Handlearn inquiry-based instructional materials (10-11 weeks long) for sixth graders were developed with the following driving question: *What is the quality of the water at a nearby lake?* The investigation of the problem begins in the classroom with several instructional activities (i.e., experiments, discussions, research) and then the students are engaged in field studies with the help of scientists. The curriculum materials place emphasis on the construction of evidence-based claims through processes of data collection, analysis, and interpretations.

The curriculum materials have been pilot tested with a small group elementary school students and during the investigation the following data were collected: videos of the group of students throughout the investigation (both in and outside of the classroom) and interviews with the students, the teacher, and the scientists before and after the implementation of the materials. The research questions that guided the analysis of the collected data are the following:

1. In what ways, if any, did the instructional intervention, support students' conceptual understandings about water quality?
2. In what ways, if any, did the instructional intervention, support students' understandings of fundamental aspects of the nature of science and the work of scientists?
3. In what ways, if any, did the use of handhelds support the outdoors inquiry-based investigations?

Initial data analyses illustrated that the handhelds played a critical role in supporting students' collecting, organizing, and sharing data. Moreover, a

pre- and postassessment was done to evaluate students' understandings of water quality, which illustrated a significantly positive difference. All participating students developed advanced understandings about the significance of lake studies and the importance of the quality of the water for an ecosystem. Through analysis of the videos it became evident that the students engaged in activities with great enthusiasm and increased motivation, which is attributed to the use of handhelds. The students appeared to be able to use the handhelds with ease and interest as they reported data collected from the field (e.g., temperature of the water, PH, NO₃, PO₄, etc.) and exchanged data with their peers. Of great interest to them, as articulated in the interviews, was the process of transferring photographic images and sounds collected in the field with the use of mobile phones to the handhelds. In general, the handhelds appeared to be supportive of the task of the inquiry-based investigations, particularly because of the fact that the students were able to concurrently gather, report, and organize the data collected at the site. Furthermore, analysis of the interviews illustrated that students reexamined and reconstructed the stereotypical images they held about scientists (i.e., Caucasian middle-age men in white coats working in laboratories) because of their interactions with the young and modern-looking metrology scientist at the site. These results suggest that the use of handhelds has the potential to support inquiry-based investigations and enhance student learning. This project offers an example of a qualitative case study regarding the use of handhelds in science education. The next section elaborates on the need for the field for more such research studies in order to advance our understandings for the role of handhelds in supporting science learning.

FUTURE RESEARCH DIRECTIONS

There is ample evidence illustrated in a number of reports and research papers about the benefits of the use of mobile wireless technologies in science education and other subjects as well. What is missing, however, is a detailed characterization of the accounts and the processes through which mobile wireless devices mediate learning. Merely extrapolating from what we know from the field of technology education will not be sufficient to understanding the distinctive possibilities for learning introduced by mobile wireless devices in science education. What the field needs is a sophisticated design framework for adapting mobile wireless devices in science

education, which takes into consideration both the unique characteristics of mobile learning *and* the nature of science. Critical in this process is gaining an understanding of what research in education and psychology reports about how people (Bransford, Brown, & Cocking, 2000), and what reform recommendations propose about science teaching (Duschl, Schweingruber, & Shouse, 2007). As Demana, Meagher, Abrahamson, Owens, and Herman (2003) argued, researchers must integrate ideas drawn out of the learning sciences with any technological innovations in handheld devices. Likewise, Roschelle (2003) pointed out the need to study the complex social practices in the classroom before schools adopt networks of mobile devices.

Built on these views, this article contends that the focus of research associated with the use of mobile technologies in education ought to be shifted to address current deficiencies in areas of goals, curriculum, and instruction in an attempt to develop a contemporary and orchestrated vision of science, technology, and society. In 1989, Hurd stated that there was *little question* that developments in science and technology impacted society and made many traditional goals of science teaching as well as much of its subject matter obsolete. Given the advances made in technology the past decade, this article suggests that there is today *no question* about how recent developments such as mobile technologies are rapidly transforming society. Transformations in society caused by advances of science and technology as, for instance, the use of mobile phones, are not necessarily mirrored in school science, or not mirrored to the desired level. Instead, changes associated with implementation of technology-enhanced curriculum materials occur localized, and thus have minimal impact (Fishman et al., 2001). Dede, Honan, and Laurence (2005) discussed the issue of scaling up success by implementing innovations in a variety of contexts:

A fundamental theme that resonates through many studies about scaling up success is how a given innovation can be successfully implemented in different contexts, including those with differences in leadership structure and availability of funding. Only innovations with strong mechanisms that foster resilience and evolution can survive the complex process of change involved in moving to scale. (p. 228)

A legitimate question that emerges, however, is whether scaled up technology innovations are the answer to reforming education. Herman (1994) argued that “technology cannot effortlessly transform education. Productive reform will require sustained attention to curricular and instructional change and to

technology solidly grounded in effective theories of action” (p. 164). David (1994), discussing the role of technology in American education, stated that “Technology by itself is not the answer to this nation’s educational problems. We believe that the power of technology will come from its combination with serious education reform” (p. 221). Likewise, Dede and Nelson (2005) stated that the conditions for the success of educational technologies in schools include complimentary shifts in curriculum, pedagogy, assessment, professional development, administration, organizational structures, strategies for equity, and partnerships for learning among schools, businesses, homes and community. Our efforts should then be directed toward integrating technology tools into a broad effort for school reform and not introducing them as *the reform*. David argued,

When technology is integrated into a broad effort for school reform, and is considered not as the instigator of reform or a cure-all but as a set of tools to support specific kinds of instruction and intellectual inquiry, then educators, students, parents, and communities have a powerful combination that may, indeed, bring necessary, positive change to this nation’s school. (p. 221)

In summing up, one thing becomes clear: “Technology-reliant educational interventions are based on a chord of innovations that harmonize and complement one another and that serve as conditions for success” (Dede & Nelson, 2005, p. 111). Built on this view, this article proceeds to suggest that researchers explore these chords of mobile technology innovations that harmonize and complement one another for the purpose of exploring ways in which these tools can support learning.

Research is crucial in better understanding the interactions between innovations such as mobile technologies and science education, and designing technology-enhanced curriculum materials that can be implemented and used prevalently in the classroom. Further qualitative research is hence recommended that: (a) exemplifies the theoretical aspects and the characteristics of design frameworks associated with mobile science learning, (b) characterizes rich and complex pedagogical practices that use mobile technologies, and (c) speaks of the details of the processes by which students come to understand science through the use of and interaction with mobile wireless devices.

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Notes

1. HandLearn (www.mlearn.cardet.org) is partially funded through a 2-year research grant to the Center of Research and Development in Educational Technology (CARDET) by the Cyprus Research Promotion Foundation.