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Unlocking the learning value of wireless mobile devices

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Abstract Many researchers see the potential of wireless mobile learning devices to achieve large-scale impact on learning because of portability, low cost, and communications features. This enthusiasm is shared but the lessons drawn from three well-documented uses of connected handheld devices in education lead towards challenges ahead. First, 'wireless, mobile learning' is an imprecise description of what it takes to connect learners and their devices together in a productive manner. Research needs to arrive at a more precise understanding of the attributes of wireless networking that meet acclaimed pedagogical requirements and desires. Second, 'pedagogical applications' are often led down the wrong road by complex views of technology and simplistic views of social practices. Further research is needed that tells the story of rich pedagogical practice arising out of simple wireless and mobile technologies. Third, 'large scale' impact depends on the extent to which a common platform, that meets the requirements of pedagogically rich applications, becomes available. At the moment 'wireless mobile technologies for education' are incredibly diverse and incompatible; to achieve scale, a strong vision will be needed to lead to standardisation, overcoming the tendency to marketplace fragmentation.

Keywords: IT-use, Portable, Wireless, Collaboration, Network, School

Introduction

Handheld computers may become an increasingly compelling choice of technology for classrooms because they enable a transition from the occasional, supplemental use associated with computer labs, to frequent and integral use of portable computational technology (Soloway *et al*., 2001; Tinker & Krajcik, 2001). Early evaluations suggest teachers and students respond to handhelds favourably. For example, 90% of teachers in a study of 100 Palm-equipped classrooms reported that handhelds were effective instructional tools with the potential to impact student learning positively across curricular topics and instructional activities (Crawford & Vahey, 2002; Vahey & Crawford, 2002).

Every new generation of learning technology brings with it a new deep conceptual issue that learning technologists must untangle in order to unlock the

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learning value of raw technological potential (Roschelle & Pea, 2002). The field of computer-supported collaborative learning has already successfully tackled two key concerns: control and representation. The concern with control led to a definition of three possible roles for the computer (Koschman, 1996):

- as tutor: an algorithm or artificially intelligent agent is predominately in control of the student;
- as tutee: the student exercises control by programming the computer (e.g. with Logo);
- as tool: teachers, activities and teams of students are the loci of control; the computer is a mediating object that is neither in control nor the object to be controlled.

Most wireless mobile technologies for education in the literature today fall in the tool camp; they do not control learning, nor do students program them.

The concern with representation follows from the important of human-machine interaction in the pedagogical and social use of technology. This concern has led to a great deal of research on the design of appropriate computer-based representations of concepts, data and other objects of classroom attention. A fundamental insight was that computational media allowed new genres of representation to arise, drawing upon the dynamic, graphical, animate, and multi-representational capabilities of computer displays (Kaput, 1992). For example, simulations that present objects that move in an idealised Newtonian world and help students visualise vectors can have strong positive outcomes on learning (White, 1993). These new representations may mediate social construction of deep understanding of a subject area (Roschelle, 1996). A body of research in computer-support for collaborative understanding has examined how such representations are used conversationally, and enable students to support each other in a process of convergent conceptual change (Roschelle, 1992; Koschman, 1996).

An exciting aspect of wireless mobile technologies for education, as described in the literature today, is that tools that first existed only on expensive desktop machines are now being made available on inexpensive handheld units (Soloway *et al*., 2001). This should ease problems of access to powerful representational tools. The graphing calculator is an example of a success story in this regard; it has made the power of multiple representations (e.g. graphs, equations, tables) readily available throughout high school mathematics classrooms in the United States and in many other countries. With more generalised handhelds, additional tools for mapping concepts, running simulations, gathering data, etc. are also appearing in handheld form. Indeed, Pinkwart and colleagues present a sophisticated framework for adapting designs from computer-supported collaborative learning to mobile handheld devices (Pinkwart et al., 2003).

Merely extrapolating from what the field has learned about control and representation in the field of computer-supported collaborative learning, however, will be insufficient to unlock the value of Wireless Internet Learning Devices (WILDs), which introduce new complexities of classroom communication. These communicative aspects relate to the new attention 'participation' has received following an important theoretical concept in educational research (Lave & Wenger, 1991). Mobile devices participate in a network that is overlaid in the same physical space in which students and teachers participate socially in teaching and learning, so two distinct kinds of participation are occurring at the same time and in the same space: the normal social participation in classroom discussion (for example) and the new informatic participation among connected devices.

A prior publication (Roschelle & Pea, 2002), identified the nature of the coupling between these two informatic and social layers of classroom communications as an important issue for further research. An informatic overlay can break the classroom social patterns, such as when students are reading email instead of participating in a classroom discussion. Similarly, in a museum setting (Hsi, 2003) visitors can be confused by the disconnection between the new informatic information space and the existing exhibition space. Likewise, in a nonclassroom medical education setting, PDAs can prove stimulus when the existing patterns of learning do not align with the new informatic infrastructure (Smordal & Gregory, 2003).

Accordingly, this paper aims to draw attention to key communication issues that will affect whether WILDs are yet another passing fad or a resounding pedagogical success. To do so, research surrounding the three classroom applications of WILD which have received the most prolonged research attention to date — classroom response systems, participatory simulations, and collaborative data gathering — are examined, drawing out issues they raise in common.

Three classroom applications

Truly wireless high-speed communications on a powerful handheld computer have new and exciting capabilities. But uses of somewhat less powerful handhelds with slower communication have been used for many years. At least three applications have been re-implemented many times, and studied by many different research teams. In order to draw out the lessons these applications have in common, each is briefly described below.

Classroom response systems

The first notably successful classroom response system, *Classtalk*, was patented in 1989 (Abrahamson *et al.* 1989). Similar product concepts have since been re-implemented many times[*]. In its simplest form, a classroom response system allows a teacher to pose a short answer or multiple-choice question. The system instantly collects and aggregates every student's response. Students hold individual handheld response units (which have variously been graphing calculators, WinCE handhelds, or specially purpose infrared beaming units) and send their response anonymously. The teacher's machine aggregates the students' responses and presents them in a coherent form, usually a histogram. From the histogram, the teacher and students can observe patterns in the variation of responses readily and use this shared point of reference to launch into pedagogical conversations. Important pedagogical uses of this capability include monitoring students' evolving understanding of challenging domain concepts and driving their small group discussions, as pedagogy which has been described as 'Peer Instruction' (Mazur, 1997). Figure 1 illustrates the use of this technology to reveal a high proportion of misconceptions in a classroom, subsequently driving group discussion. A later poll,

[*] Eleven current commercial products have been identified. Examples include:
eInstruction (http://www.eInstruction.com),
TI-Navigator (http://education.ti.com/us/product/tech/navigator/features/features.html), and
Discourse (http://www.ets.org/discourse/)

also shown in Fig. 1, then reveals a pattern of convergence towards the correct concept.

While the technology executes a fairly simple function, often limited to a multiple-choice pop-quiz, research has revealed that there is more to this technology than meets the eye. Early adopters of classroom response systems have consistently described the technology as a catalyst for a significant, powerful shift in the classroom climate, pedagogy and resulting learning (Abrahamson *et al*., 2000; Davis, 2003; Dufresne *et al.,* 1996; Owens *et al.*, 2002). Formative assessment is known to be a very powerful intervention (Black & Wiliam, 1998) and these systems enable students to receive much more feedback than normal. Importantly, students can see where fellow students share their misunderstandings, and that they are not alone. Further, because the displayed responses are anonymous, embarrassment is reduced (Owens *et al*., 2002). Teachers can check for understanding with conceptual questions (with common misconceptions as possible answers) and are frequently surprised by the results (Dufresne *et al*., 1996). A teacher can consequently engage students in knowledge-rich conversations, through peer instruction (Mazur, 1997) or other techniques.

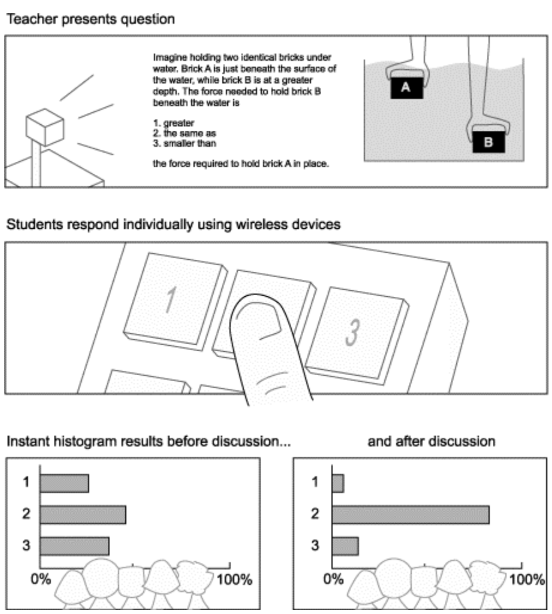

Fig. 1. Using a response system to aggregate students answers before and after discussion

In the overall resulting classroom system, the role of the technology is small but extremely valuable. The technology provides anonymity, speed of response collection, and the ability to produce a shared visualisation that enhances mutual pattern recognition. But non-technological social processes still carry much of the burden of teaching and learning: asking questions, explaining, clarifying, summarising, etc. The most recent and thorough examinations of this technology (using Texas Instruments graphing calculators and a pre-release networking product) emphasise a virtuous cycle of changes that result in a classroom that uses the system (Davis, 2003; Owens *et al*., 2002). The cycle maps onto the four factors of successful classrooms identified in a groundbreaking summary of learning science research (Donovan *et al.,* 1999). The classroom becomes more learner-centred, assessment-centred, knowledge-centred, and community-centred. These are powerful and apparently robust effects from a fairly simple use of WILD technology. Further they do not appear to be limited by subject matter, and can be significantly extended beyond the range of multiple choice and short answer questioning. For example, 'image map assessments' have been proposed in which students' marks on images are aggregated (Roschelle & Pea, 2002). Others are working at Cartesian aggregation spaces of contributed mathematical functions (Kaput, 2002). Many more kinds of classroom response aggregation are possible. Clearly, pedagogical application underlying classroom response systems deserves much more research attention in the coming years.

Participatory simulations

Participatory simulations (Wilensky & Stroup, 1999; Colella, 2000) use the availability of a separate device for each student and the capability of simple data exchanges among neighbouring students. They enable students to act as agents in simulations in which overall patterns emerge from local decisions and information exchanges. Such simulations enable students to model and learn about the many scientific phenomena relating to decentralised systems: swarming ants, traffic jams and flocking birds (see for example, Colella *et al.*, 2001). To date, participatory simulations have been implemented using technology as simple as Lego bricks with tiny embedded processors and infrared exchange capabilities (Borovoy *et al.,* 1996). Other research groups have implemented participatory simulations with graphing calculators and a prototype (partially) wireless network (Wilensky & Stroup, 2000) or with Palm handhelds and infrared beaming (Soloway *et al*., 2001).

A prototypical scenario for participatory simulation is modelling the spread of disease (Colella, 2000). All but one student device starts the simulation clear of disease; one is ‘infected.’ As students move around, their devices exchange messages with the fellow students they are facing. Consequently, the infection can spread. In some implementations, an overall record of the number of infections over time is captured and displayed as a graph, allowing students to observe the overall trend. Students then discuss the results and design experiments to see if they can control the spread of disease. For example, they can attempt to quarantine the infected parties or slow their rate of social interaction.

The ‘participatory’ aspect of these simulations is directly enabled by the technology, which enables a ‘secret’ (such as who is initially infected) to be distributed within the class and subsequently allows messages about that secret to be exchanged and acted upon locally. Researchers who have studied participatory simulations are enthusiastic for two reasons. First, these simulations appear to make very difficult ideas around ‘distributed systems’ and ‘emergent behaviour’ more accessible to students (Resnick, 1996; Wilensky & Stroup, 2000). Second, participation embeds student engagement in a playful social space (Colella, 2000; Stroup *et al*., 2002). Students have rich conceptual resources for reasoning about and thoughtfully acting in playful spaces, and thus can more easily become highly engaged in the subject matter. More recently, researchers have begun explore how participatory simulations can be used for mathematical content unrelated to distributed systems. For example, a classroom of students can all create the same function, but with different parameter values (Kaput, 2002; Stroup *et al*., 2002). When the resulting functions are graphed, students can see an ‘emergent’ visualisation of the parametric family of functions.

Collaborative data gathering

The pedagogical use of technology in science classrooms with the longest track record is the use of ‘probes’ to gather and graph data from live experiments instantaneously (Mokros & Tinker, 1987; Nachmias & Linn, 1987). Probes allow students to gather accurate data, and by graphing it quickly, allow students to focus on the interpretation of their data, rather than tedious processes of recording and plotting it. Thus, probes support the long-term pedagogical drive towards 'inquiry-centred' science classrooms, by making scientific experiments easier for students to perform and analyse (Tinker & Krajcik, 2001).

Presently 'probeware' is available from several companies for handhelds including Palms and graphing calculators. The Palm evaluation (Vahey & Crawford, 2002; p.25) found that:

> The popularity of probes among PEP teachers points to the usefulness of handheld computers for scientific inquiry. The ImagiProbe system by ImagiWorks was the most noted software package, and probes were found to be essential peripherals. ImagiProbe was deemed crucial by almost 25% of responding projects across all grade levels, and was ranked number 1 at both the high school and middle school levels and number 3 at the elementary school level.

A very popular scenario for handheld probe use is water quality evaluation (Vahey & Crawford, 2002). Students take their Palms and probes to a nearby stream and each student takes measurements at different points along the streambed. The students combine their data by beaming or aggregating on a common teacher machine. Back in the classroom, they use their handhelds to graph and analyse the combined data set. Hence, connectivity supports the scientific inquiry process by allowing students to aggregate data sets. Teachers using the Palms reported, to their surprise, that handheld use resulted in more cooperative work. The beaming capability was especially well liked, whereas the standard Palm 'HotSync' to a desktop machine was extremely problematic in classrooms.

Other applications

Classroom response systems, participatory simulations, and collaborative data gathering are not the only pedagogical applications for WILDs. (See other papers in this issue for additional examples.) As the use of WILDs in schools gains experience, these three applications may not be the most important applications. Nonetheless because WILDs are so new, research on their classroom use is fairly scarce. Hence it makes sense to extract all the lessons available from these examples.

Lessons about connectivity

The Internet offers a great experimental playground of networking possibility (Lessig, 2001); it has proven to be an incredibly malleable and productive infrastructure. Thus, in theory, a mobile device that is wirelessly enabled can do anything. Yet, in practice, wireless Internet use on small handheld screens has been problematic. Despite intensive design and strong hype, Wireless Application Protocol (WAP) has been a spectacular failure (Kiili, 2002). Equally surprising, Short Messaging System (SMS) has succeeded beyond anyone's expectations (Rheingold, 2002). This alone should be enough to suggest that 'wireless' or 'internet' is not specific enough to describe what sorts of informatic coupling are desirable among WILDs.

Indeed, the most common Internet applications can be quite problematic in classrooms. Schools, for example, have been tempted to ban instant messaging because it enables cheating and disruptive behaviour (Pownell & Bailey, 2001).

Further, attention is a teacher's most precious commodity, and no teacher wants her students' attention focused on messaging with friends outside of class (Schwartz, 2003). Notice, however, that none of the case study WILD applications require connectivity beyond the local classroom, nor do any require a generic messaging capability that would allow students to 'pass notes'.

Instead the WILD applications which were surveyed emphasise *a local messaging topology* among participants in mostly face-to-face settings. This topology is either hub and spoke (with the teacher at the centre) or peer-to-peer (with the teacher having some ability to direct which students can intercommunicate). For example, in probeware settings, the teacher probably does not want students to be able to pull data sets off the web, and may have strong pedagogical reasons for initially allowing data exchanges only in working groups rather than among the whole class.

Further *teacher-controlled communications* predominate. In classroom response systems, the only communication is to and from the teacher. In participatory simulations, the applications are structured to allow only messages relevant to the classroom content, thus not offering students more freedom than they need. Moreover, peer-send capability of Palm infrared beaming gives the teacher the ability to visually monitor which students are sending messages to each other.

Spatially directed communications are particularly important as well. In participatory simulations, spatial proximity organises the messaging topology, allowing students to enact a process like the spread of disease. With probeware, it is important both that students place their probes in particular spatial locations in the stream and that they can exchange data with particular students who are nearby. Even classroom response systems have a spatial component. *Classtalk* gave teachers a classroom map, so they could see where various responses came from on a classroom seating chart.

Short, asynchronous structured data messages predominate over long general purpose text messages (such as in email) or long-term conversations (such as telnet or Napster). Indeed none of the three case study applications enables or requires text messaging; most send just a handful of bytes in each message. Further, the rather time-consuming heavy-weight 'synchronisation' process of exchanging data among Palm handhelds and a teacher workstation has proved to be very cumbersome in classrooms (Vahey & Crawford, 2002).

Finally, *aggregation* is a key feature across these cases. In classroom response systems, aggregation allows teachers to address the *variation* in understandings present in the classroom without having to address each individual student, but eliciting the patterns in variation across all students. In participatory simulations, it allows students to see a graph that represents the overall trend in the joint simulation. In collaborative data gathering, it allows students to form more comprehensive shared data sets. A *shared public display* is important in making these aggregates available for discussion.

School is by no means a simple place to introduce a WILD without running into massive opposition from powerful stakeholders. Schools, for example, have already imposed harsh restrictions on the degree to which students can use a school-supplied device personally because some students are found to have downloaded pornography and shared it on school premises (Dean, 2002). But some of the killer pedagogical applications that emerge for WILDs may not require (or even be well-matched) to the mainstream applications such as instant messaging, email and the web. Thus WILDs may not need (or at least teachers may want the capability to disable) the mainstream applications with the most potential for abuse, while enabling applications that feature teacher-controlled messaging topologies, spatially directed communication, short structured data messages and aggregation.

Indeed, one might question whether the word ‘Internet’ belongs in a pedagogical device given that commonly noted properties of the Internet include its lack of regulation, its support for multiple protocols and its decentralised nature. Should the ‘I’ be taken from WILD in favour of a more controllable wireless LAN or peer-to-peer environment that better matches schools’ requirements?

One advantage of peer-to-peer networks (such as supported by IR beaming) is that they require no infrastructure, and thus are easy to install and maintain (Roschelle *et al.*, 2003). However, in the long run, it is probable that this advantage will not be sufficient to overcome a big disadvantage: it is difficult for teachers to organise whole-class activity (such as handing out and collecting work, and *Classtalk*-like aggregations) with only a peer-to-peer network.

Since the aggregation capability carries much pedagogical power, wireless hub-and-spoke LAN topologies with a local server will probably gain renewed focus. Such configurations are becoming affordable with the prevalence of 802.11 and Bluetooth wireless networking (see Chang *et al.*, 2003). But the ability to search the web and access resources outside the school is also an important pedagogical activity. The original meaning of the ‘Internet’ (Leiner *et al*., 2003) was a network among networks, connecting heterogeneous, incompatible LANs via gateway servers. This appears to provide exactly the right conceptual model to carry forward into education, as it offers custom functionality for the classroom (such as rapid aggregation), control to the teacher, and access to external resources. Liu and colleagues present an instance of this model in more detail (Liu *et al*., 2003).

Lessons about pedagogical technology

New technologies encourage researchers to dream up rich possibilities for online interaction. It can readily be imagined how learning might be improved if students could see their class schedules online, review their grades, retrieve homework, submit assignments, participate in discussion groups, annotate common artefacts, ask question of their instructor, and so on . . . all with a personal, low-cost, mobile, wireless handheld device. There are two problems with this vision. First, it relies on placing an interface to instructional management and learning tools on a small screen with limited input possibilities. Second, it provides little insight into the social practices of WILD use; indeed it presumes that the social practices surrounding education remain largely unchanged as the technology moves from large ‘desktop’ interfaces to small handheld ones.

In contrast, it can be noted that the most successful Internet and handheld technologies tend to involve rich social practices built around rather simple (but uniquely functional and reliable) technology. SMS again comes to mind. Youth around the world have developed incredibly rich social practices around incredibly simple (but cheap and reliable) technology (Rheingold, 2002).

These three case studies emphasise this direction towards simple, well-honed technology and rich, pedagogically developed social practices. Indeed, in each case, the technology performs a small, well-defined function uniquely well, but much of the rest of teaching and learning is left to social practice. Probeware excels at collecting and sharing data, and little else. Yet it supports a transition to inquiry-based scientific practice in the classroom. Participatory simulations excel at exchanging small, extremely simple data messages among spatial neighbours. Yet students can readily become socially involved in designing experiments. For example, they can try to slow the spread of disease by quickly assigning those infected to quarantine, or by having fewer social partners. Much of the learning occurs in design and debriefing phases that are not mediated directly by the technology. In classroom response systems, questions are often authored and posed to the class offline (for example, by drawing the question on the blackboard); the technology performs only the essential functions of gathering responses anonymously and instantly summarising them in a publicly displayed histogram. Almost all the subsequent teaching and learning occurs outside the technology, as students and the teacher compare, elaborate, explain, critique, argue, etc. about the patterns of response.

This fairly weak coupling of informatics and social practice in these case studies permits many apparently ironic outcomes. For example, the essential pattern of the classroom can become ‘peer learning’ despite a technology that has no peer-to-peer communication capabilities (such as *Classtalk*). The sense of community in the classroom can evolve rapidly, despite the lack of any ‘online community’ tools. Students become more involved in designing and interpreting controlled experiments, despite software that has no sense of variation in parameters. (To perform an experiment with participatory simulations, students only change their spatial movement; the software has no knowledge that it is involved in a ‘different’ experiment. The parameters are embodied by the students and are not explicit constructs in the software). Students can perceive receiving much more individualised assessment feedback, despite the fact that all they ever see is a shared, anonymous public representation of the group’s thinking. From these apparent ironies, the causal arrow from technology affordances to social practice is often quite crooked. Consequently, research attention should be directed at identifying those simple things that technology does extremely and uniquely well, and to understanding the social practices by which those new affordances become powerful educational interventions.

Lessons about scale

An important attraction of WILDs is the potential to have an impact on learning on a large scale. The underlying economic premise is that the low cost of WILDs will make ubiquitous access to computation and communication available, and consequently students will be able to use technology much more often, with greater integration into their studies. A frequent caution among educational experts, however, is that merely having computers or connectivity is not enough — appropriate applications are essential. This observation leads directly to the problem of scale facing WILDs: the lack of a common software or connectivity standard for authors of such applications to target. It is expensive and financially risky for software authors to write software for many different varied platforms, and educational software is a fragile business which does not support much risk taking (Roschelle & Kaput, 1996). Presently, the WILDs being explored by researchers in the WMTE community span a diversity of radically incompatible operating systems (e.g. PalmOS, WinCE, Java, and Symbian). These will not run the same applications, making the deployment of a 'killer pedagogical application' to many students very expensive and complicated. Further, their communication capabilities are not equivalent. Palm's fine infrared beaming support is not matched on the other platforms. Texas Instrument's graphing calculators (while widely available in schools) have a proprietary communication protocol. Even the commonality among those devices that support 802.11 wireless networking is at an extremely low level. There is no high level shared data exchange mechanism appropriate for the pedagogical applications described above.

Without more commonality in the computational and communications platforms, it may be hard to get to scale. More commonality might come about in two ways.

One possibility is that a single platform could become dominant. For example, presently in high school in the United States, Texas Instruments graphing calculators are nearly ubiquitous, which enables textbooks, teacher professional development and application developers all to target this platform. Consequently, graphing calculators are making an impact in American education (and in many other countries as well) at scale. But the graphing calculator market share may fall as students find a wider range of attractive devices competing for their dollar, such as handheld organisers, phones, digital cameras, and MP3 players. Given this range of attractive devices, schools may find an increasing diversity of devices entering their walls, and pedagogical application developers may face greater difficulties in installing their applications at scale.

A second possibility is that pedagogical application standards are established and conformance becomes an important factor in what students buy and bring into school. While this possibility might be attractive, it is politically hard and slow to set standards. At the moment, it is not even clear what standards might be needed.

With regard to scale, Probeware has fared the best in these case studies. Probeware has been around for a long time, and has maintained a constant vision of science inquiry over that time. This vision has been attractive to a large and growing number of science teachers, who have been willing to buy Probeware add-ons to the handheld units (graphing calculators or Palms) that their students own. Probeware has accommodated platform incompatibilities by continual re-implementation on each successive platform by a few small companies. Certainly this is one pattern by which WILD pedagogical applications may get to scale, finding a core vision that has a large potential user base and building the essential functionality for every possible platform.

Participatory Simulations and *Classtalk* have yet to become broad scale phenomena. In the case of *Classtalk*, lack of a suitable classroom wireless networking platform has been a frustration to the developers. Even as large companies, such as Texas Instruments, have become involved, suitable classroom networking products have been slow in coming. Participatory Simulations are perhaps too new to be judged fairly with respect to scale. A key element for their eventual scale-up is the degree to which classroom networks make spatially organised data exchanges simple. Typically radio-based wireless networks have no notion of the varying spatial proximity of simulation participants within a classroom (as compared, for example, to short-range, directed infrared beaming) and may frustrate attempts to scale this technology. Further, participatory simulations require short, frequent, asynchronous messages; the wireless LANs schools purchase may not be well-optimised for these properties.

Conclusion

WILDs present an exciting opportunity for educational technology, as the proceedings of the WMTE conference and this JCAL Special Issue should make clear. But it will take concerted, focused effort from research to realise the possible benefits. Understanding of the essence of 'wireless and mobile' needs to grow in refinement from today's generic enabling standards like 802.11 and SMS to tomorrow's pedagogically specific requirements like teacher-controllable messaging topologies and rapid aggregation of short, asynchronous data messages. Research needs to help an understanding of the surprising lack of surface resemblance between enabling technology and desirable social practices of learning. A clearer identification of the separate roles of technology-based communication and non-technology-based interpersonal communication is needed, and also the ties that bind these together in exemplary teaching and learning. Finally, it is necessary to adopt a critical attitude to the economic plausibility of a ubiquitous, mobile, personal teacher and learning platform that will run all the best pedagogical applications. Concerted effort among leaders in the research and educational community will need to drive the raw technologies that will arrive in classrooms towards enough of a common platform that scale for pedagogical applications becomes feasible.

These challenges are part of a thematic emphasis on coupling. Wireless and mobile technologies in education will succeed to the extent that coupling is increasingly understood:

- within the informatic world, in terms of appropriate communication infrastructures, protocols, messaging standards, and processing capabilities, distributed across devices;
- within the social world, in terms of appropriate mutual engagement of a teacher and students in social practices of learning, for example, emphasising learner-centred, assessment-centred, knowledge-centred and community-centred practices;
- across the informatic and social worlds, by finding the combinations in which the unique, powerful, and reliable capabilities of WILDs enable and motivate the unique, powerful, and reliable properties of social interaction, especially given mappings of enabling technology and social practice that may be superficially ironic.

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