Unlocking the potential of wireless learning

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Unlocking the Potential of Wireless Learning

VLADLENA BENSON

Kingston University, UK

ABSTRACT

Wirelessly enabled learning offers distinctive benefits to teaching and learning because of portability, low cost and improved communication capabilities (Kukulska-Hulme & Traxler, 2005). This article presents an exploratory review of several categories of wireless technologies, their successful applications in higher education institutions and challenges from the educator's perspective. Recent research reports a diverse range of wireless learning strategies, see for example Parsons *et al.* (2006), and current applications of wireless technologies in teaching are still emerging. Conclusions drawn from successful experiments using mobile devices and wireless networks in universities may inspire others and help reassess the challenges ahead. Further studies are needed to explore and successfully apply wireless capabilities driven by the pedagogy, rather than the technology. This paper attempts to outline various teaching strategies and relevant categories of wireless applications focusing on the relationship between the pedagogy and the supporting technology. It concludes with suggesting issues for further research, especially the need to thoroughly evaluate the learning benefits of wireless applications.

Introduction

The abundance of mobile wireless devices and constantly increasing bandwidth allows a wider choice of teaching and learning methods (Roschelle, 2003). Applications of wireless technologies in teaching and learning are still developing. Benefits of wireless are evident: learners on the move can use mobile devices to take their learning materials into a rich variety of environments and social practices. Advanced communication capabilities of mobile devices, relatively low set up costs and location independence offer distinctive benefits to teaching and learning (Parsons *et al.* 2006). Current research describes an extremely diverse range of mobile learning applications structured around various pedagogic strategies (Linn & Eylon, 2006). Earlier research revealed that both educators and students responded favourably to the introduction and use of mobile devices for teaching and learning, and Soloway *et al.* (2001) indicate that instructors emphasise their potential to have a positive impact on student learning. At present wireless technology in education is used principally in research studies (Roschelle, 2003), although many practitioners (Kukulska-Hulme & Traxler, 2005) envisage wireless will become an integral part of learning and teaching processes. The challenge is how to make the best use of the learner's mobility, to provide both intelligent information delivery and engaging learning experiences. This paper presents an exploratory study of wireless applications in higher education institutions and aims to draw attention to key factors that may affect successful adoption of mobile technology in pedagogy. To do so, research surrounding the three categories of wireless learning applications are discussed in the context of relevant pedagogic and technological issues: wireless Local Area Networks (LANs) for collaborative learning, mobile learning through game playing, and classroom response systems.

Collaborative learning, or the grouping and pairing of students for the purpose of achieving an academic goal, has been widely advocated in pedagogical literature (Paavola *et al*. 2004). According to Gokhale (1995), collaborative learning refers to an instruction method in which students at various performance levels work together in small groups towards a common goal. The students rely on one another's learning as well as their own. Thus, the success of one student helps other students to be successful. As Vygotsky (1978) concludes, students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. Diversity of participants in a group in terms of knowledge and experience contributes positively to the learning process. Studies by Gokhale (1995) indicate that cooperative learning methods also improve problem-solving strategies because the students are confronted with different interpretations of a given situation.

Wireless technology can facilitate interactions between individual learners and the teacher. Research on the learning benefits of questions in *individual learning* has shown that the learning environment can be significantly improved by the application of varied questioning approaches (King, 1990). The use of appropriate questions has the potential to engage the learners and focus them on specific objectives. Questioning helps students practise retrieval and application of information.

Technology (Local Area Networks)

For many higher education institutions, going 'completely wireless' is difficult to achieve and may even be unnecessary. In order to make a distinction between the types of wireless networks available, we discuss the most commonly used architectures of wireless LANs; this section of the paper briefly describes the technical infrastructure. The first wireless LAN standard, IEEE Std. 802.11[1] (Gast, 2002), was adopted in 1997. It addressed local area networking which uses wireless technology to carry information between nodes of the network. Connected devices communicate over the air to other devices, called stations, which are within close proximity to each other. This standard defined the media access control (MAC) and physical (PHY) layers for a LAN with wireless connectivity. The 802.11 MAC layer provides functionality to allow reliable data delivery over the wireless PHY media. Mobility of wireless stations may be the most important feature of a wireless LAN. Wireless LANs are owned and operated by the user, such as the higher education institution or a service provider, and are available within a fixed environment. The 802.11 architecture comprises several components and services that interact to provide station mobility transparent to the higher layers of the network stack. A wireless LAN station is any device that contains the functionality of the 802.11 protocol, and a connection to the wireless media. A station could be a laptop PC, handheld device, or an access point. Stations may be mobile, portable or stationary, and all stations support services of authentication, privacy and data delivery (Gast, 2002).

The most basic wireless LAN architecture is a set of stations that recognise each other and are connected via the wireless media in a peer-to-peer mode (Figure 1). This form of network topology is referred to as an Independent Basic Service Set (IBSS) or an ad hoc network. All the stations within an ad hoc network must be within a fixed proximity due to range signal strength limitations of the network.

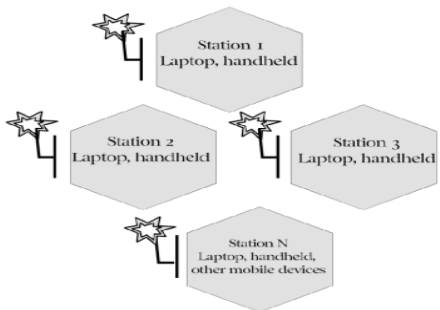

Figure 1: Ad hoc topology of wireless LAN

A more powerful topology of wireless LAN is the Infrastructure Basic Service Set, which offers connectivity to a wired network or other ad hoc wireless LANs. It is a set of mobile stations with a component called an access point (AP). The access point provides a local transmit function for the basic set of stations. All nodes communicate with the access point and no longer communicate directly. The access point may also provide connection to a wired network or a distribution system (Figure 2). Wireless networking standard 802.11 addresses mobility, security, reliability, and the dynamic nature of wireless LANS while maintaining compatibility with existing wired networks.

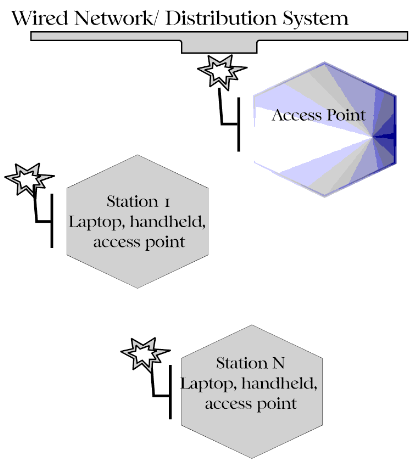

Figure 2: Infrastructure Basic Service Set

Technology offers educators more than just tools to facilitate teaching and learning; it changes the classroom dynamics even in the most common teaching strategies. This paper addresses applications of individual and collaborative learning scenarios supported by a variety of wireless technologies and outlines applicable social learning practices. Widely adopted wireless teaching strategies enabled by wireless LANs or wireless classroom response systems, which have received the most notable research attention, are examined, focusing on lessons learnt through the recent studies.

Pedagogy

As stated earlier, the active exchange of ideas emphasised in collaborative learning increases motivation among students working in small groups and also promotes critical thinking (Bruner, 1985). Research by Aronson & Patnoe (1997) suggests that collaborative teams achieve at higher levels, and research by Johnson & Johnson (1986) indicates that students who learn in groups retain information longer than students who work individually. Shared learning gives students an opportunity to engage in discussion, take responsibility for their own learning and contribute to the group.

In order to effectively implement face-to-face collaborative learning activities in classrooms, academics may face the kinds of problem described in Aronson & Patnoe (1997). In learning teams, students exchange ideas verbally making it difficult to keep a record of student interaction. This in turn leads group learning to be result-oriented rather than process-oriented. Also, competing pressure between students in a group may lead to domination of higher ability students in a learning activity. As a result, lower ability students may be deprived of their learning opportunities. Studies by Zurita & Nussbaum (2004) have shown the creation of an effective collaborative learning environment is determined by the following five key factors:

1. *Individual responsibility:* each member must be responsible for his or her own work, role and effort to learn.
2. *Mutual support:* each team member must help in the teaching of the other members of the group.
3. *Positive interdependence:* the main goal of collaborative activities is the group goal. Therefore, collaboration is considered a success when every member of the group has interacted and accomplished their individual goal.
4. *Social face-to-face interactions:* the decision-making process must include discussions between all collaborators. Productivity is therefore influenced by the ability of the group to efficiently exchange opinions, negotiate and work together.
5. *Formation of small groups:* communication, discussion and achievement of consensus can be only carried in small groups, and each member of the group must be physically close to the other members.

Communication patterns and social interactions in a traditional classroom can be reshaped using wireless devices. A mobile environment facilitates face-to-face interactions, known as the key factor for obtaining effective results in a collaborative work group (Johnson & Johnson, 1986). The role of technology, and computers in particular, in collaborative learning has been widely explored in current research and has led to the definition of three categories of computer applications/roles for educational purposes (Koschman, 1996). Roles served by enabling technology in teaching and learning can be one of the following:

1. *Tutor:* educational software or an artificial intelligence agent is 'in control' of a student.
2. *Tutee:* the student exercises control by programming the computer.
3. *Tool:* instructors, learning teams and the activities are mediated by means of a computer.

Most wireless mobile technologies are used as the third category. A mobile device is a powerful educational tool; as a tool it does not control learning, nor do students program it. The following section describes how a combination of the wired internet and mobile devices connected through a wireless network can facilitate classroom interactions and mediate collaborative learning activities. Practices are outlined which maximise the effectiveness of collaborative learning and alleviate problems related to diversity of students' skill levels and social interactions in group work.

Collaborative learning scenario with wireless LAN

Cortez *et al.* (2005) describe application of wireless technology facilitating group work in face-to face teaching and learning sessions. A teacher was equipped with wired internet access and a central wireless device communicating to students' mobile devices. Before the start of a teaching session, the teacher downloaded collaborative activities to be worked on in class from the Internet on to a personal digital assistant (PDA). In the classroom session students were equipped with PDAs interconnected in a peer-to-peer mode. The activity was distributed to the students' devices over the wireless network (IEEE 802.11b). Collaborative learning software divided students into small groups, in which they worked face-to-face with the support of technology. Cortez *et al.* (2005) advocate randomising the assignment of students to groups per session to promote new social interactions, thus enabling each student to have a chance to work with a range of participants.

The teacher monitored and controlled the flow of activity as a mediator via a PDA. The software provided information to the teacher about which group struggled with the activity and which task might have been too challenging for the entire class, thus requiring assistance from the teacher. In the experiments presented in Cortez *et al.* (2005), students worked in groups of three and were required to answer a set of multiple choice questions collaboratively via their handheld devices. Students within each group worked through the set of multiple choice questions sequentially and negotiated if they disagreed on the answers. A unanimous agreement before answering a question was reached through a collaborative discussion using handhelds. Once all the members of the group provided the correct answer, the group could proceed to the next test question.

Students were given immediate feedback and the teacher/mediator was aware of the weakest points which needed further discussion. Once the activity was completed, it was possible to upload results to the Internet-based system, such as a Learning Management System or the project website.

Software supporting this collaborative learning scenario comprised the following layers:

- *Network layer* based on TCP/IP and UDP protocols working over a wireless LAN (IEEE 802.11b) in a peer-to-peer mode without the access to the Internet or wired LAN. The network allowed asynchronous data interchange, synchronous text messaging, and file transfer.
- *Activity layer* provided services and tools for multimedia integration. The activity layer was responsible for tools for developing applications and integration of the collaborative layer and the supporting applications within the network.
- *Collaborative activity* comprised a problem posed for a group of students. Students in a group had to give an answer to the problem and in case of conflicting opinions to arrive at a consensus.

Each activity was annotated with the relevant XML (Extensible Markup Language) specification and enabled with the following set of components:

- *Group creator:* creates random groups of students and communicates the group assignment to the devices of the teacher and the students;
- *Group holder:* provides storage capabilities of files and data for each group and supports the communication of group members;
- *Question controller:* directs the flow of each activity including logic, answer evaluation, collaboration and response to each question.

The statistical results of the empirical evaluation in Cortez *et al.* (2005) suggest that students working in a face-to-face collaborative mode perform significantly higher than working individually. The authors conclude that the mobile learning environment encourages students to discuss questions in a collaborative manner and thus leads them to obtain better test results from the first attempt. Cortez *et al.* (2005) believe that randomising the process of student assignment to groups promotes new social interactions between students, giving each student a fair chance to work with other participants and promoting a sense of cohesion in the collaboration processes. During the experiments a higher level of motivation among students was observed. The researchers explain that it was due to expectations created by the experiment and the change in the classroom dynamics produced by the introduction of wireless.

The students engaged in a collaborative activity reasoned and learned together, sharing their knowledge and thereby reducing the number of erroneous answers compared with the scores from students working individually on the same test. All students participated and gave their opinions in face-to-face interactions that were mediated by technology. The experiment showed that the wireless learning environment stimulates social and communication skills as well as supports learning within a subject area. The correlation of the learning process with the successful collaboration process has been singled out as requiring further research.

Wireless enabled learning through game playing

Learning through game playing has been drawing the attention of researchers for decades. Malone & Lepper (1987) reported a strong relationship between learning and intrinsic motivation, based on the study of students using computer games for learning. Further research confirmed the efficiency of computer games in linking the motivation to 'win the game' and 'learn the material' (Lepper & Cordova, 1992).

Schwabë & Goth (2005) explored the potential of wireless technology in application to learning through mobile gaming.They based their trials of mobile learning around the challenge of familiarising students with the university during their induction. Groups of students were presented with various tasks referring to locations, events or history of the university. The mobile handheld devices provided students with the positioning system and interior and exterior maps of the university. The mobile gaming scenario was based on synchronous collaboration between participants equipped with mobile devices. Students cooperated with each other and competed in groups to complete the race around the university to achieve the highest score in the set of tasks assigned to them. The architecture of the mobile game relied on each client device (PDA) to maintain its private state in the ongoing game. Each mobile device stored the relevant game data. Players' PDAs were programmed to retain necessary data to enable game continuity even if the connection to the network server was lost. PDAs communicated to the server through a wireless LAN. The server, acting as a central communication point throughout the game, was responsible for broadcasting the updates of data to the wireless LAN stations. The web client exchanged data with the server over HTTP (Hypertext Transfer Protocol). Access points constantly broadcasted identifiable MAC address information used for location based services. The narrow broadcasting range of a wireless LAN cell allowed for efficient provision of location-based information. Wireless LAN chips are integrated in most PDAs and mobile phones, hence, wireless LANs can be used for access to simple classic internet services or more sophisticated applications such as collaborative gaming and Voice over Internet Protocol (VoIP).

Swabë & Goth (2005) used a two-step evaluation approach for the Mobilearn project. Firstly, motivational aspects of the game were investigated in the context of their relationship to the technical usability of the learning game. Experimental games lasted approximately 40 minutes and included 20 participants between the ages of 19 and 25. Students found the following features of the mobile devices most useful: orientation on the map using the location based services; interaction with other group members; and the ability to access task questions at any time. Most respondents rated the size of the hand held device as the most important feature, especially in the game where mobility was an issue. This was followed by the data input capabilities, and the general display options and software handling options.

To create a challenging and engaging game, it is necessary to consider structural elements in the game design as proposed by Prensky (2001). Characteristics of the learning game should be carefully thought through by the teacher, including the rules followed throughout the game, objectives that players try to achieve, progress measurement throughout the game, challenge and/or opposition leading to the players' involvement, social interaction, and, finally, the storyline of the game.

Classroom response systems

Applications of wireless LAN and specialised mobile devices are still fairly novel in universities. However, simple wireless devices with slow communication speed have been used for years in higher education. A classroom response system (CRS) is interactive software that allows instructors to assess student performance instantaneously in a classroom. The use of a CRS allows a teacher to pose a question and obtain immediate feedback from every student. Learners can answer multiple choice, true/false, yes/no and survey-style questions that the teacher presents to the class. Use of various questioning approaches facilitated by technology allows students to understand why they missed specific questions and allows for repetition within the learning process. Commercial CRS offer a wide range of functionality and scalable options for varying class sizes.

A typical classroom response system comprises a receiver unit connected to the instructor's computer and a set of wireless response pads. CRS software running on the teacher's computer allows questions to be posed through common word processing packages, such as Microsoft PowerPoint®. Each student receives a response pad, which works similarly to a TV remote control, and uses it to give answers to the teacher's question. Once students have given their answers, the results can be displayed providing feedback to both teacher and the class. CRS software analyses the responses and provides a coherent representation of them, usually in the form of a histogram. Teachers, as well as students, can observe various patterns of the responses. This form of feedback can serve as a starting point for a pedagogical conversation or group discussions; also, it provides valuable feedback for monitoring students' understanding of challenging concepts. Figure 3 (overleaf) demonstrates the sequence of events in a CRS-enabled classroom, starting with the presentation of a test question by the teacher through to guiding learners to knowledge–rich discussions and further knowledge assimilation.

A teacher can engage students in a discussion based on peer learning, while the technology works as a catalyst in this pedagogical setting. Mazur (1997) describes adoption of a CRS to instigate peer learning, and demonstrates the use of technology to 'reveal a high proportion of misconceptions in a classroom, subsequently driving the discussion'. Students are asked to answer a question on a specific subject using CRS, and anonymous distribution of responses is shown to the class. Students discuss the question in small groups and take the poll again. Mazur describes a pattern of convergence towards the correct answer

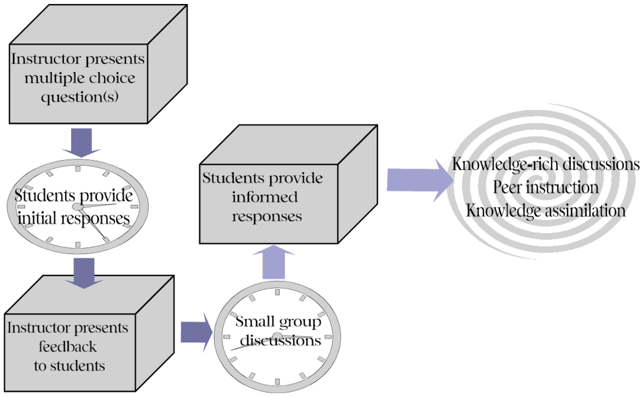

Figure 3: Using a wireless CRS in face-to-face learning

in student responses and suggests a consequent engagement of students in knowledge-rich conversations through peer instruction or other pedagogic techniques.

In this scenario, wireless technology assumes a comparatively straightforward role of collecting responses for a multiple choice test or a pop quiz; however, the technology provides a significant change in the classroom atmosphere and dynamics. Davis (2003) reports application of CRS as a powerful tool that enables positive transformation of the classroom climate, pedagogy and, consequently, learning.

Wireless CRS provide for both formative and summative methods of assessment. Students gain confidence through receiving more feedback and sharing their learning experience with colleagues, gaining confidence that they are not alone in their misconceptions or difficulties (Davis, 2003). The feedback aggregated by the CRS is anonymous, hence students lacking confidence are given the opportunity to be engaged in classroom dynamics. The answers from students are instantaneously aggregated and the feedback to students is automated. Correct answers help build students' confidence and mistakes can be immediately rectified. The classroom equipped with a CRS becomes more learner-centred, assessment-centred and knowledge-centred (Mazur, 1997). Applications of these systems offer new opportunities to educators and, undoubtedly, pedagogical strategies enabled by CRS are in need of further research attention.

Discussion

The experiments considered in this paper use technology to improve learning. Continuous advancement of mobile devices and wireless communication technologies has the potential to achieve synergy with traditional and other computer-based learning methods. The collaborative learning scenario by Cortez *et al.* (2005) integrates the use of the wired internet and mobile devices in a peer-to-peer communication mode. The Internet is used as a communication media for accessing and exchanging activities and results, enabling an easy and transparent delivery of activities to the teacher and recording of results. Higher motivation and achievement levels are among the benefits achieved by providing learners with systematic feedback, as shown through the application of wireless CRS (Davis, 2003). Not only do weaker students gain confidence, but through peer support, everyone in the classroom benefits from the opportunities opened by technology, developing critical thinking through discussion and problem-solving.

Until now the technology by itself has not fulfilled the expectations to change learning dramatically or become a revolutionary educational tool. The incorporation of wireless into the teaching process within a collaborative learning framework leads to an educational environment in which technology is used to control interactions between participants. The technology provides information, regulates tasks, administers rules and roles, and mediates the acquisition of new knowledge. Wireless technology offers significant advantages to educators and learners, and presents an important opportunity, but certain points need to be addressed when applying it:

- Technology is a means, not an aim. The learning aims should be put first and then enabled by technology in a way transparent to the user.
- The classroom remains an interactive environment. The technology facilitates the move away from teacher-centred classrooms. The technology empowers students and serves as a mediator in the learning process.
- The teacher must be provided with flexible and rich resources as an integral element of the mobile learning environment. Teachers should be well informed about new teaching techniques and prepared to work as mediators in a mobile student-centred classroom.

It has been noted (Roschelle, 2003) that wireless applications show a surprising lack of interface similarity between enabling technology and desired social practices of learning; for example, emphasising learner-centred, knowledge-centred or assessment-centred practices. United efforts among researchers in education, the community and wireless hardware/software manufacturers are needed to drive the development of wireless applications delivering meaningful learning experiences and stimulating students' thinking through real world problems.

Conclusions

Whether or not wireless learning technology can achieve its potential and facilitate students' learning effectively clearly depends on how it is used by teachers and learners. Therefore, it is important to provide appropriate support to learners through help functions of the wireless device and to immerse these technologies with everyday teaching and learning activities.

Current mobile technologies for education are exceedingly diverse and are regarded as complex by educational practitioners. To meet users' expectations they should:

- provide a good initial experience and be learnt quickly by new users. The benefits of using mobile learning should be apparent to the learner. The first use should offer a straightforward, acceptable way of locating the necessary learning materials;
- support multiple modes of information access. Learning content, activity navigation, etc. should be clearly described and presented to the user in a clear fashion;
- avoid brittleness (Beale & Lonsdale, 2004). A single action, such as selecting something accidentally or skipping over a content segment or a topic should not have a drastic and unrecoverable effect on the learning process.

Finally, it is necessary to take a critical approach towards accessing the economic viability of the mobile applications in education. Most endeavours of wireless educational strategies have been developed based on the enthusiasm of the teachers and technology-inquisitive students. Further pedagogical research and involvement of the leading manufacturers is needed to drive the development of a common technological platform effectively supporting of a mobile and personal instructor and learner.

Future trends

Wireless technology changes at a fast pace with more electronic devices arriving in the consumer market constantly. Mobile learners want the convenience of getting their information and learning resources when and where they want them, on whatever device they choose (Neal, 2006). Audio podcasting is becoming an accepted and desired method of teaching for mobile learners. In the enhanced podcasting delivery mode, the teacher can integrate chapters, bookmarks, images, video and clips. Video podcasting is in its experimental stages but is quickly gaining popularity as an instructional tool. Mobile learners today are equipped with iPods, handhelds, smartphones, or an advanced combination. The technology is driven by its users, and therefore wireless technology in education has a bright future.

Note

1 IEEE 802.11LAN/MAN Wireless LANS <http://standards.ieee.org/getieee802/802.11.html>.

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About the author

Vladlena Benson is a Principal Lecturer in the School of Information Management at the Kingston Business School, which she joined in 2003. Vladlena's research interests include e-learning and use of ICT in higher education.