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Designing collaborative, constructionist and contextual applications for handheld devices

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Abstract

This paper explores current applications for handheld devices and questions which of these make full use of the unique attributes of handheld devices in order to facilitate learning in a pedagogically sensible manner. In order to do so, the paper presents a functional framework which analyses handheld application in relation to their use as well as the pedagogical underpinning, if any, that informs their development. Our framework currently consists of seven distinct categories of application, which we term: administrative, referential, interactive, microworld, data collection, location aware and collaborative. We argue that three categories, namely data collection, location aware and collaborative, are particularly suited to learning with handheld devices when they are informed by collaborative, contextual and constructionist learning theories. Furthermore, we contend that applications of the type just outlined deserve further research since they are not attempting to replicate, or even augment, existing learning scenarios but rather they try to create new learning opportunities which would not be possible without (mobile) technology. Finally, the authors introduce a number of applications and learning scenarios that they have developed for handheld devices and explain their position within the framework.

Keywords: Collaboration; Constructionism; Contextualisation; Constructivism; Handheld devices; Categorisation; Framework

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1. Introduction

Many authors are arguing that the growth of pervasive, ubiquitous, computing will have a large impact on learning. For instance, Bull et al. claim that it is inevitable that every student will have a portable wireless device (Bull, Bull, Garofalo, & Harris, 2002). Pownell and Bailey (2000) propose that this evolution is part of the fourth wave in the development of technology with very small computers and wireless connectivity delivering 'anyone, any time, anywhere learning'. In USA, the National Technology Leadership Summit, of teacher educator associations, state that "ubiquitous computing will be a widespread force in schools by the end of the decade or sooner" (Bull et al., 2002).

While these statements might reflect a certain naive degree of optimism, or worse a simply technological determinist viewpoint, given the "ready-at-hand" nature of these devices there are sound reasons to believe that wireless portable technology will have a role to play in the way we learn (Naismith, Lonsdale, Vavoula, & Sharples, 2005; Roschelle, 2003; Soloway et al., 2001; Tinker, 1997). Although cost, adaptability and scalability are among the motivations most often cited for using handhelds in learning, it must be remembered that the use of technology must be driven by pedagogical considerations rather than financial, logistical or technical reasons.

2. Related work

Currently, the most popular applications for handhelds are referential or presentational in nature, with dictionaries and organizers commonly available. Educational applications, neither referential nor focused on content delivery, also exist. These range from reflective logs, allowing learners to record observations in situ, to technologically augmented environments, enabling learners to explore and interact with their surroundings.

Due to the rapid changes in the PDA and mobile phone markets the devices used to deliver these applications vary widely. However, the two markets are converging. Smartphones now come with extra facilities traditionally associated with PDAs such as Internet access, video, and multiple application programs, and PDAs are beginning to incorporate telephony functionality. Within these markets different software platforms are vying for market share, the most prominent being Microsoft CE, Palm OS and Symbian OS. The lack of a common platform poses difficulties to deliver large-scale solutions and has led researchers to call for more standardization (Roschelle, 2003). However, if prior experience in the field of computer standardisation is anything to go by, it is more likely that the final "standards" in the area will be set by market forces rather than pedagogical needs. In any event, the functionality of handheld devices, both PDAs and smartphones, are constantly increasing, moving them from the market of electronic diaries to that of small laptops.

Researchers have attempted to devise classifications for this emerging field. The scheme formulated by Gay, Rieger, and Bennington (2002), differentiates between applications based upon the educational objectives which motivate their use. These range from 'productivity', which can be supported by the simplest tools, to 'communication and collaboration' which require complex applications. Roschelle discriminates solely upon activity claiming that instances of the three main types, classroom response systems, participatory simulations and collaborative data gathering, have been implemented many times (Roschelle, 2003). Most recently, Naismith et al. (2005), divided applications based upon the educational theory that they support. The ''theory-based categories'' identified were behaviourist, constructivist, situated, collaborative and 'informal and life-long learning'.

3. Functionality framework

We have developed a framework for categorising handheld educational applications which views the mobile learning design space in terms of both application function and pedagogical underpinning. While the classifications previously mentioned have their merits, we argue that ours is more extensive in that it merges these two perspectives of functionality and pedagogy into one framework. Furthermore we contend that our framework clearly points to the area of the design space which should prove most fruitful for developing educational applications for handheld devices, namely collaborative, constructionist, contextual applications.

The categories identified to date range from administrative applications, not driven by any real pedagogical philosophy, to collaborative applications that encourage knowledge sharing while making use of the learner's physical context and mobility. The comprehensive list is as follows: administration; referential; interactive; microworld; data collection (subdivided into scientific, multimedia and reflective); location aware and collaborative (Fig. 1). There is progression

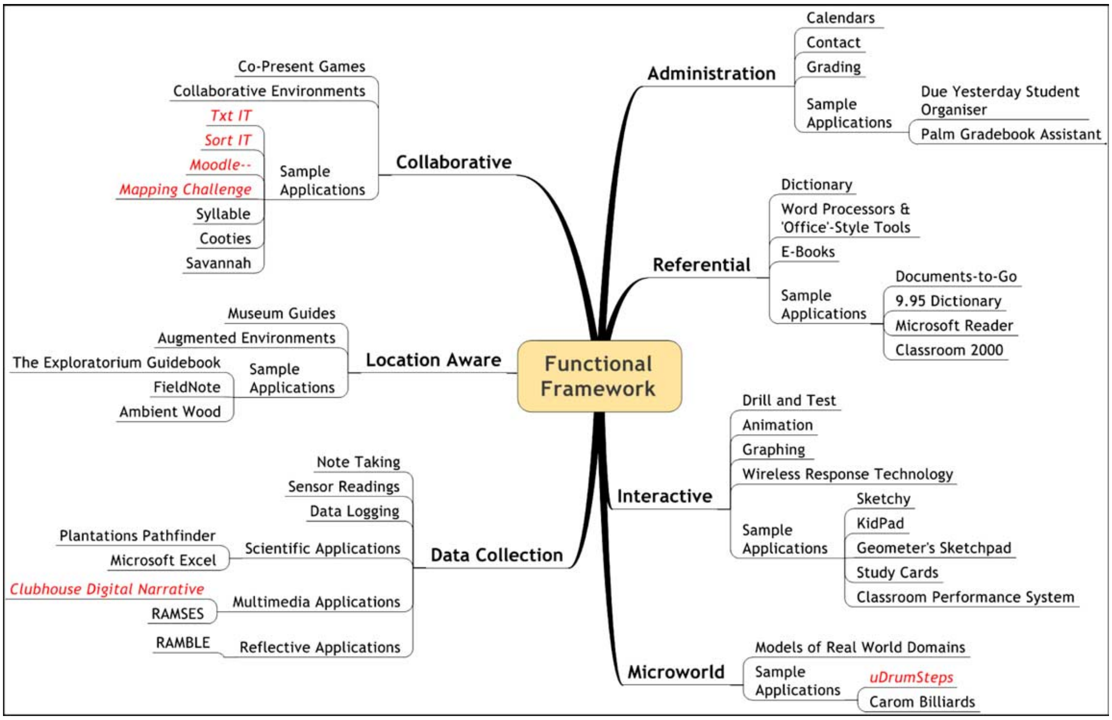

Fig. 1. Functional framework.

between the categories with each one generally incorporating some functionality of what has appeared before. We argue that the initial categories merely replicate applications available on fixed desktop, or laptop computers, while the later leverage off the unique attributes of handheld devices.

3.1. Administration

Administrative applications focusing on information storage and retrieval are widely available. Generally concentrating on scheduling, calendars and grading, they could be described as education focused Personal Information Managers. A popular example of this type is the 'Due Yesterday Student Organiser'.[1] Other applications, described as groupware, make use of the communication features handheld devices offer by allowing users to share their calendars and co-ordinate schedules. In general, applications in this category do not scaffold or support knowledge construction and merely replicate in a convenient manner tools already available on traditional platforms.

3.2. Reference

Referential applications such as 'office style' tools, dictionaries, translators and e-books, allow for the accessing of content at the place where learning activities occur by making use of the portability and mobility of handheld devices. Although offering basic administrative functionality, such as note taking, these applications generally do not go beyond information delivery. Examples of e-book tools are 'Microsoft Reader'[2] and 'Adobe Reader.'[3] MS Pocket Word[4] and 'Documents-to-Go'[5] move a step further by allowing users to store, access and annotate documents that would normally be accessed on desktop computers. This accessibility to information is also used for 'Just-in-Time' applications which support learning in work environments. Though widely available, these tools are not particularly educationally inspired and tend to replicate traditional applications.

3.3. Interactive

Within this category, applications transcend information management and content delivery by focusing on engaging users through a 'response and feedback' approach. Although they make use of the input and output features of handheld devices, many of these applications are of the 'drill and test' type aimed at encouraging memorization of information for individual learners through multiple choice style quizzes. 'Study Cards'[6] available for graphing calculators is a characteristic example. Wireless response technologies, as made popular on TV

[1] http://nosleepsoftware.sourceforge.net/index.php.
[2] http://www.microsoft.com/reader/downloads/ppc.asp.
[3] http://www.adobe.com/products/acrobat/readermain.html.
[4] http://www.microsoft.com/windowsmobile/about/tours/ppc/2002/pocketword.mspx.
[5] http://www.palmone.com/us/solutions/personal/docstogo/.
[6] http://education.ti.com/us/product/apps/studycards.html.

game shows, are also representative of interactive applications. Sketchy,[7] an application allowing users to create their own simple animations, exemplifies a less data-driven and more creative focus to the development of interactive applications which leverage off the touch screen interface of many handheld devices. Overall, interactive applications are slightly more creative than those in previous categories and generally exploit the unique features of the devices to engage in, admittedly low order, learning activities that might not be easily achievable with traditional techniques.

3.4. Microworld

Educational microworlds allow learners to construct their own knowledge through experimentation in constrained models of real world domains. By providing tasks within real world settings, learners are able to engage with topics in a novel and innovative manner. The literature argues for their merit as teaching tools (Jonassen, 1996) and this has led to the development of many microworlds based upon traditional desktop platforms. To date, not many such systems have been developed for handheld devices perhaps due to their computational limitations. 'Carom Billiards', aimed at exploring simple geometric concepts within the context of billiards games (Horton & Wiegert, 2002), is one of the few examples of mobile microworlds.

3.5. Data collection

Applications in this category make use of the ability of handheld devices to record data and information about their environment. They constitute a genuine attempt to use technology to create learning experiences that would be either unfeasible, or at least problematic without handheld computers. Furthermore building on the administrative and referential categories, learners are generally able to access relevant content while also recording information.

Within this theme, three sub-categories are identified: scientific, reflective and multimedia.

Scientific: The use of mobile technology is being broadly adopted by science educators and is well documented in the literature; for an example of this see Stanton Fraser et al. (2005). Scientific data collection focuses on encouraging participants to learn more about their context through recording relevant information and providing immediate feedback through on-the-spot analysis.

Reflective: Applications in this category expand on the administrative and referential themes allowing learners to access content and diaries whilst also encouraging reflective practice. Common in medical education, they support students in recording observations, in the working/learning environment, that can later be used to aid in reflection (Alderson & Oswald, 1999). RAMBLE[8] (Remote Authoring of Mobile Blogs for Learning Environments) exemplifies this approach.

Multimedia: Handheld devices are now capable of capturing images, sound and video and this ability can be put to a number of uses. In the simplest form the technology can

[7] http://goknow.com/Products/Sketchy/.

[8] http://ramble.oucs.ox.ac.uk/index.html.

facilitate note taking in classes or meetings. Multimedia data can also provide the basis for reflection. However, at present, there is no software for handhelds that facilitates on-the-spot reflective processes. More interestingly, ability to capture multimedia means that handhelds can be used as very low cost devices in projects with an emphasis on digital creativity. The 'Digital Narrative Project' (McGreen and Arnedillo Sánchez, 2005) portrays a clear example of this.

By and large, the type of interactions that applications in the data collection category encourage are particularly well suited to mobile devices. The combination of communication features, computational capacity and the mobile nature of the devices would be difficult to replicate otherwise.

3.6. Location aware

Applications in this category aim to contextualise learning activities by enabling the learners to interact appropriately with their environment; they make use of the unique attributes of handhelds and are, occasionally, collaborative in nature. Going beyond the mere collection of environmental data, these applications use sensors or positioning systems (Bull et al., 2002) to allow the devices to interact with the learner in a context aware manner. Thus, they present appropriate referential information or encourage the users to explore their environment. Applications in this area stretch from museum guides to augmented environments for treasure hunts. Ambient Wood which encourages learners to construct their own understanding of a habitat through the exploration of augmented woodlands (Cole & Stanton, 2003) illustrates this approach.

3.7. Collaborative

Building on the previous categories, collaborative applications aim to encourage knowledge sharing while making use of the learner's physical context and mobility. In addition to utilising the mobility, communication features and computational capacity of handhelds, these applications attempt to create a learning environment inspired by collaborative learning principles. A number of interesting applications have been developed in the area of 'Collaboration', in particular co-present collaboration. These include co-present problem solving games such as 'Syllable' (Zurita & Nussbaum, 2004) and location based games such as Savannah (Benford et al., 2004).

In summary, much of the work presented across the categories has had limited success 'in the field'. The 'killer app' for mobile learning, the application that will force these devices into learning environments everywhere, is yet to be found. Nonetheless, progress has been made and lessons have been learnt. These include the following: there is no correlation between a complex solution and an appropriate educational solution; the most interesting applications to date facilitate learners to look away from their screen in order to engage with their surroundings and peers; these applications are particularly suited for learning. They facilitate collaboration and support some of the social practices associated with learning.

4. Pedagogical underpinning

Given the constant development of features and functionality for handheld devices, it is understandable that the research agenda of the field frequently focuses on exploring the possibilities created by new technical capabilities. While there are many interesting technical opportunities associated with handheld devices, the use of technology in learning settings must be founded upon pedagogical considerations. The challenge is to create solutions that are educationally appropriate rather than technologically complex, in order to avoid the development of applications that are often let down by complex views of technology and simplistic views of social practice (Roschelle, 2003).

Having introduced the functional breakdown of applications within our framework, we turn to analyse what pedagogy, if any, underpins their implementation. We do this by examining the educational concepts associated with each category and by presenting sample applications. Some of these have been developed by the authors and provide scope for a more detailed account of lessons learnt through their design and implementation (Fig. 2).

4.1. Administration

Administrative applications have *little pedagogical* philosophy underpinning their implementation. Building upon the initial 'Personal Organiser' functionality of PDAs, they focus on information storage and retrieval for educational domains. While these tools are useful for time management and logistics, they do not facilitate learning or encourage learners to engage with topics.

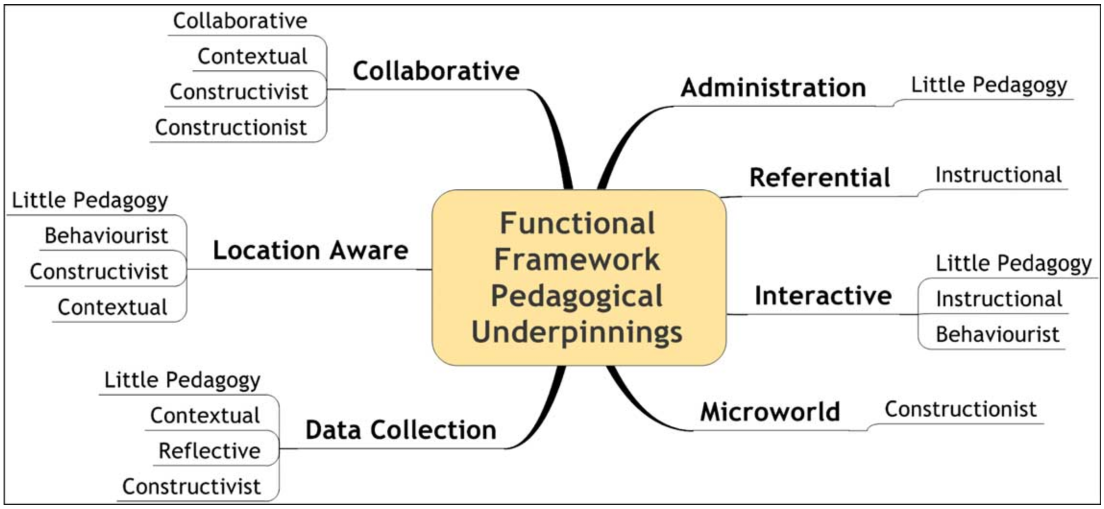

Fig. 2. Pedagogical underpinning.

4.2. Referential

Referential applications are primarily built upon an *instructional* philosophy of learning. They aim to support learners by delivering large amounts of textual data onto a small and limited device. Although they provide users with the potential to access content in 'new' spaces, areas where they previously did not have access to technical resources, these applications do not scaffold or support knowledge construction. Furthermore, studies have questioned the benefits of using handheld devices to this end given the well established usage patterns of reference books and other information sources (Smordal & Gregory, 2003).

4.3. Interactive

Mainly aimed at eliciting interactions and delivering appropriate feedback, these applications can adopt a number of educational approaches depending on the interaction-respond pattern they require. Tools with a creative focus, as the aforementioned Sketchy, are engaging, provide valuable creative outlets and can support a variety of learning styles. Others, of the 'drill and test' type such as the BBC Bitesize[9] service, are inspired by *behaviourist* approaches to learning. Built on the belief that learning is enabled by creating an association between a particular stimulus and a response, interactions within this context are often limited to answers to multiple choice quizzes. While this is a particularly popular approach in e-learning systems, it is a "fairly basic application of mobile devices in learning" (Naismith et al., 2005, p.12). Moreover, this behaviourist approach is at odds with the potential of handhelds to "provide more direct ways for learners to interact with materials in an authentic learning context" (ibid).

4.4. Microworld

Applications within this category encourage creation and exploration in learners, are more consistently informed in pedagogical principles and tend to adopt a *constructionist* approach to learning. uDrumSteps, a mobile version of DrumSteps, an application for percussion composition developed by the authors, is representative of this approach. Based firmly on constructionist concepts which advocate that learning occurs "especially well when the learner is engaged in constructing something for others to see" (Papert, 1993), uDrumSteps enables users to create, manipulate, edit and save original pieces of percussion music through an intuitive interface. Whilst we believe the educational underpinning to be sound, as shown by the PC implementation (Jennings & Tangney, 2002), limitations on mobile devices result in a 'restricted' version. For instance, the insufficient processing power on handhelds makes the sound of each beat to be slightly out of step with its visual representation and the absence of MIDI capabilities restricts the number of sounds available. In all, these limitations hinder the meaningful interactions learners can have with the musical concepts and reduce the effectiveness of uDrumSteps as an educational tool. There is a lack of microworlds for handheld devices, but our own experience would suggest that this approach could be educationally valuable. However, given that microworlds

[9] http://www.bbc.co.uk/schools/revision/.

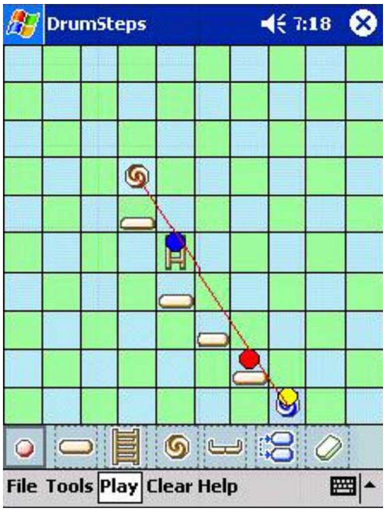

Fig. 3. uDrumSteps.

are often technically sophisticated applications, the current limitations of handhelds can reduce their educational impact. As the technology gains computational capacity, this constructionist approach should become more beneficial (Fig. 3).

4.5. Data collection

Initially, implementations in all sub-categories had little pedagogical basis with handheld devices being used as administrative assistants for logging data. More recent implementations have been built around stronger social practice and more appropriate technical functionality thus, applications that fall into this category tend to be informed in a variety of pedagogical conceptualisations.

Scientific: Current scientific applications have a *contextual* focus supporting 'field-trip' methodologies of learning. As learning is taking place in a rich physical environment, filled with real world objects and connections, the concepts presented can be meaningfully contextualised (Falk & Dierking, 2000). The aforementioned SENSE project, enabling devices to collect data and communicate with sensors that are 'in the field' while also providing instant feedback through on the spot data analysis (Stanton Fraser et al., 2005), is a good example of this pedagogical approach.

Reflective: Often built on simple technology, these applications encourage *reflective* social practice by focusing on storing information in the learning context for later evaluation and reflection. They frequently encourage collaboration by enabling learners to share their reflections with a wider community utilising a variety tools. This expansion is understandable as the reflective process is an important component of collaboration (Brown, Collins, & Duguid, 1989). While this approach is most common in medical studies, it has also been implemented in teacher training. In this instance, it was found to be a particularly effective tool for taking field notes during observations, these were later used as a basis for feedback for the student (Crippen & Brooks, 2000).

Multimedia: Current implementations tend to adopt a *constructivist* methodology requiring learners to construct new ideas or concepts based on their current and past knowledge (Bruner, 1966). An example of this approach is the Digital Narrative Project[10] (McGreen and Arnedillo Sánchez, 2005) run by the authors. Built on the belief that visual media is an exceptional medium for encouraging real world problem solving (Smith & Blankinship, 2000) and learners' reflection (Bransford, Sherwood, Hasslebring, Kinzer, & Williams, 1990), this project supports the participants in expressing their thoughts through a 'Digital Narrative'. While the overall process is similar to other digital film projects, the tools used are different. Thus, the learners shoot all of their "footage" and record their "soundtrack" on smartphones. In addition, the smartphones allow the participants to make their multimedia available to collaborators by sending the images and sound via the multimedia messaging service (MMS) to 'foneblogs'. Due to current limitations in handhelds the final edit takes place on fixed PCs. As the incorporation of multimedia capability with handheld devices, particularly mobile phones, becomes more ubiquitous, the opportunity to use these devices to communicate in new ways, beyond those of telephony, will increase. The Digital Narrative Project embodies a collaborative, contextual, constructionist approach to learning with handheld devices.

We argue that these data collection applications make appropriate use of handheld devices in learning. They build on the attributes of the technology in ways that could not be replicated by other devices. Generally, the technology plays a small and well-defined role of data collection, within a wider educational project. Much of the actual learning, as Roschelle (2003) argues, is found in the design and debriefing phases of these projects, which are not mediated directly by technology.

4.6. Location aware

Building on the use of sensors and positioning data used in scientific data collection, these applications attempt to allow learners to engage with, and be engaged by, their context. The *contextual* approach supports several learning methodologies ranging from those instructional in nature to more constructivist ones. The museum guide type of applications is representative of the previous and aim at delivering content appropriate to the learner's position. While occasionally technologically complex they yield limited educational benefits and, if access to technology was not an obstacle, they could be replicated with similar learning outcomes on different devices. Recent applications, such as the aforementioned Ambient Wood, have a stronger educational underpinning attempting to engage learners with their surroundings and to make them explore their environment through touch, sight and sound. The combination of location aware technologies and a contextual learning approach facilitates learners to construct meaningful contextualisation of concepts, which has proven learning benefits (Michie, 1998).

[10] The Digital Narrative: 'Honey I Blew up the Planet' website is available at http://blake.cs.tcd.ie/clubhouse05.

4.7. Collaborative

We argue that this category makes better use of the features of mobile technology to support meaningful learning scenarios that would not be feasible otherwise. Informed in the belief that learning is inherently a social activity (Roschelle & Teasley, 1995; Vygotsky, 1978), these applications aim to facilitate learner *collaboration*. They do so by utilising the unique attributes of handhelds in order to support knowledge sharing through co-present games or collaborative contextual environments. Applications in this category normally incorporate elements of the previous categories. For instance, Savannah, a collaborative tool, has a strong *contextual* approach associated with the 'Location Aware' category. Likewise, Cooties[11] and Geney (Danesh, Inkpen, Lau, Shu, & Booth, 2001), two collaborative problem solving applications, have strong links to the *constructionist* 'Microworlds' approach.

5. Collaborative, constructionist and contextual applications

From our analysis of current mobile learning research and applications, we argue that the most educationally appropriate applications currently available are built on a combination of collaborative, contextual, constructionist and constructivist principles. With this in mind, the authors have developed a series of applications informed in this paradigm.

TxtIT: Expanding on the attributes of the 'Interactive' category, this application examines using the low-threshold technology of short message service (SMS) to support interactivity in the classroom (Markett, Arnedillo Sánchez, Weber, & Tangney, 2004). In particular, TxtIT aims to overcome two problems which hinder student participation in class: shyness and large class sizes. A simple system was built which allows students to send an SMS text message to a phone number and for that message to appear on the screen of the lecturer's laptop. Thus students can anonymously ask questions without interrupting the flow of the class. The lecturer can choose to respond immediately to the question or wait until a number of questions arise and deal with them at an appropriate point in the class. The SMS are available in an after-class website where the lecturer and all students can further develop the interaction via an online threaded discussion forum. In particular, the interface allows the poser of the original question to indicate if they have received a meaningful response to their query. The system has been tested in a number of classes and the results to date are reported in a companion paper in this journal (Markett, Arnedillo Sánchez, Weber, & Tangney, 2006) (Fig. 4).

Mapping challenge: This is a collaborative, location aware, interactive, treasure hunt game. It requires co-ordination between spatially separated members of a team, visiting locations in an urban area, to collect symbols in order to complete tasks (McGreen and Arnedillo Sánchez, 2005). It builds on the belief that mobile phones are well positioned to support contextual learning since they take the learning out into the physical context where the knowledge will be used (Cereijo Roibás & Arnedillo Sánchez, 2002). In doing so, it provides learners with

[11] http://goknow.com/Products/Cooties/.

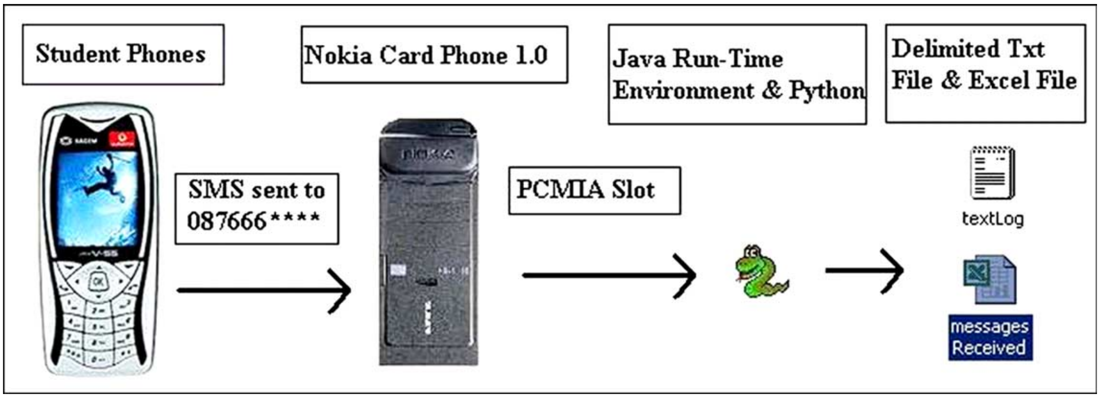

Fig. 4. TxtIT.

GPRS enabled smartphones to interface with the system, an interactive website supported by a database. Informed by collaborative principles, the application is designed to support key events in the collaborative processes such as 'task co-ordination', 'synchronisation of the task', 'negotiation and discussion' and 'support for individual and group achievement' (Churchill, Snowdon, & Munro, 2001; Dillenbourg, 1999; Zurita, Nussbaum, & Sharples, 2003). After an initial briefing in which learners are informed of their role in the overall 'game', there is no personal/face-to-face means of co-ordinating the activity among the distributed members of the group. Using the system to store results of intermediate stages of the exercise it is possible to co-ordinate the progress of the overall group throughout the tasks. Our approach uses handheld devices to facilitate collaboration across a distributed team that otherwise would not be able to communicate. It combines social and technical support allowing learners to work effectively as a team to solve a group task (Fig. 5).

SortIT: This is a collaborative problem solving application informed by a *constructionist* approach to learning. It attempts to support learners in constructing their own understanding of the solutions to sorting problems and problems of categorisation. Given an initial set of objects on their handheld devices learners are asked to sort, or categorise, the items by moving them around on the screen. By providing a large initial data set and using the IR functionality of the devices, which allows learners to 'swap' their objects, the application can also facilitate collaboration. In addition, to encourage users to reflect on standard steps that can be applied to sorting similar sets of objects, a number of reflective data logging functions are provided. For instance, a simple text log area allows learners to record the sequence of instructions used to sort a set while a drawing panel allows them to draw directly onto the screen to externalize algorithms. Learners can beam the diagrams across to co-learners and use these to explain the sorting decisions they have made. Likewise, the logs and diagrams can later be used as a basis for discussion around the choices learners made. While this tool was initially designed for teaching sorting algorithms to computer science students, its approach has sufficient functionality to sort, or categorise, almost anything that can be represented graphically. No matter what the data set, the learning process remains the same with the handheld devices supporting a collaborative and reflective process which encourages the learners to construct their own understanding of sorting algorithms (Fig. 6).

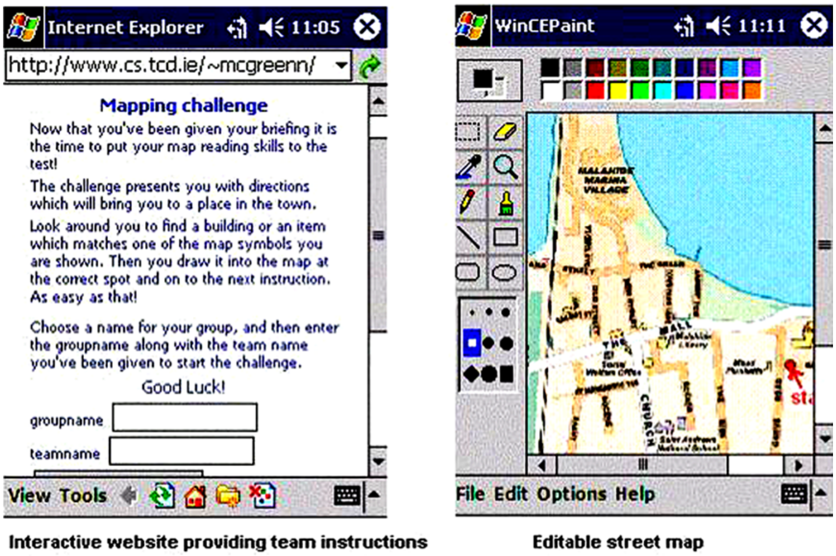

Fig. 5. Mapping challenge.

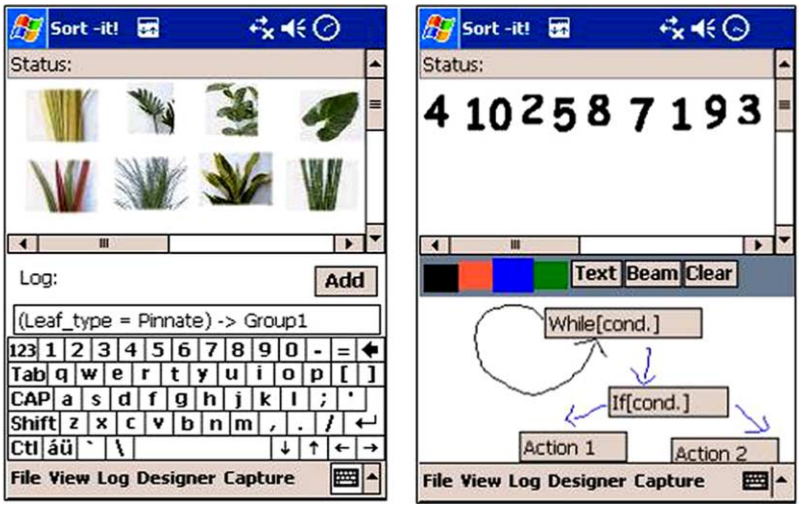

Fig. 6. SortIT.

6. Conclusion

To conclude, we propose that there are sound reasons to believe that handheld devices will have a role to play in the way we learn. The extent to which this opportunity will be taken will depend on how the technology is used. From our analysis of the current mobile learning research and applications, as well as our own experience with developing handheld applications, we draw two observations.

Firstly, many applications currently available merely leverage off the mobility of handheld devices to replicate or augment existing learning scenarios. If the goal of 'anyone, any time, anywhere learning' is going to be met, we will need to broaden our own horizons and create new innovative learning opportunities which would not be possible without handheld devices.

Secondly, we believe that the most appropriate use of handheld devices is to be found in the synthesis of appropriate use of the technology and sound educational underpinning. From our framework we have identified three categories – data collection, location aware and collaborative – that make appropriate and innovative use of handheld devices. We also identified that the most appropriate underpinning of these categories can be found in the educational philosophies of collaboration, contextualization, constructionism and constructivism.

Building on from this experience, we are currently developing a collaborative, contextual, constructionist and constructivist virtual learning environment appropriate for handheld devices. Building on the open source VLE 'Moodle', we have added contextual functionality and interfaces for a number of handheld devices, including PDAs and mobile phones.

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