Using Mobile Technology to Create Flexible Learning Contexts

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Abstract: This paper discusses the importance of learning context with a particular focus upon the educational application of mobile technologies. We suggest that one way to understand a learning context is to perceive it as a Learner Centric Ecology of Resources. These resources can be deployed variously but with a concern to promote and support different kinds of mediations, including those of the teacher and learner. Our approach is informed by sociocultural theory and is used to construct a framework for the evaluation of learning experiences that encompass various combinations of technologies, people, spaces and knowledge. The usefulness of the framework is tested through two case studies that evaluate a range of learning contexts in which mobile technologies are used to support learning. We identify the benefits and challenges that arise when introducing technology across multiple locations. An analytical technique mapped from the Ecology of Resources framework is presented and used to identify the ways in which different technologies can require learners to adopt particular roles and means of communication. We illustrate how we involve participants in the analysis of their context and highlight the extent to which apparently similar contexts vary in ways that are significant for learners. The use of the Ecology of Resources framework to evaluate a range of learning contexts has demonstrated that technology can be used to provide continuity across locations: the appropriate contextualization of activities across school and home contexts, for example. It has also provided evidence to support the use of technology to identify ways in which resources can be adapted to meet the needs of a learner.

Keywords: Zone of Proximal Development, Context, Mobile Technology

1 Introduction

The question at the heart of this paper is how we can understand context in a way that will enable us to use mobile technology effectively to help learners (and teachers, peers and parents) to adapt the resources they find within a particular context to best support their learning needs. Previous research has indicated that the impact of technology is heavily dependent upon the specifics of the educational culture into which the technology is introduced (Wood, Underwood, and Avis, 1999). This impact does not reduce with the new forms of smaller and less visible technology. Wireless, mobile, and ubiquitous technologies bring with them the opportunity to link a learner's experience across multiple locations. This should enable her to make selections about where and how she wishes to work with greater flexibility than is offered by tethered desktop technology alone. Such pervasive forms of technology also enable researchers to collect data about a learner's experience, including her use of technology, across multiple contexts with previously unattainable reliability. In other words we are poised to take advantage of the potential offered by these technologies for the creation of learning experiences that will engage learners in activities across multiple contexts and that can support collaboration and communication across time and space. However, to do this we need to understand more about the nature of what constitutes a learning context. The question of how best to apply mobile technologies in learning contexts is still open for discussion and exploration.

The focus of this paper is the presentation and evaluation of a framework for the characterization of a learning context as an *Ecology of Resources*. We discuss the nature of a learning context and in particular the resource elements that comprise such a context. We explore the way in which technology can be used to bridge different locations and how it might adapt, or help learners to adapt a learning context to meet their needs. Two case studies extracted from projects that use portable technology to link learners' experiences across multiple locations are then presented. The role of these case studies is to explore the ways in which such technology can be used to link different contextual resource elements to test out the usefulness of the *Ecology of Resources* framework. The two case studies between them offer evidence about the use of technology in the home, school, science laboratory and field. They encompass young learners tackling basic numeracy skills and older students conducting environmental science experiments. This case study approach enables us to illustrate the use of the framework to evaluate different learning contexts and scenarios. As space is limited here, the case studies are quite briefly described and concentrate on aspects that best highlight the framework categories. References to more detailed descriptions of the research from which the case studies were extracted are provided later. In the final discussion we consider the results that arise from these case studies in order to evaluate the usefulness of the design framework.

2 What is Context?

Existing work within education, computer science and Artificial Intelligence as applied to Education (AIED) has started to explore the nature of learning contexts. In education, studies of contemporary practice describe classrooms as Social Learning Contexts (Mercer, 1992), in which the organisation of the learning resources, including the computer, will influence the manner in which these resources are used and the nature of the context. Each individual class will have its own unique culture and brand of learning environment (Smagorinsky and Fly, 1993). In computer science, specifically, the ubiquitous computing community, context is defined in a manner that will enable the development of 'context aware' applications. This work has resulted in definitions of context such as that offered by Dey (2001), which characterises context as: "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". This has been critiqued by Dourish (2004) who proposes greater attention be paid to the nature of human activity, and Chalmers (2004) who highlights the way that history influences ongoing activity. He suggests that an individual's experience and history is part of her current context.

In the AIED and mobile learning literatures the nature of context is discussed in terms that combine the educational and technological perspectives. This research community has explored how we can design adaptive technology that takes a learner's context and potential collaborators into account (Greer, McCalla, Cooke, Collins, Kumar, Bishop, and Vassileva, 1998, and Murray and Arroyo, 2002, for example). By moving beyond the desktop and outside the classroom context, wireless, mobile and ubiquitous technologies have been shown to engage learners in hands-on experience and activities in real world learning situations. As we have previously identified (Smith, Luckin, Fitzpatrick, Avramides and Underwood, 2005; Stanton Fraser, Smith, Tallyn, Kirk, Benford, Rowland, Paxton, Price, and Fitzpatrick, 2005) such activities can lead children to be more imaginative in their understanding, can yield both motivational and cognitive benefits and offer learners greater ownership of their data.

Finally, there has been some early work to explore how modeling can be applied in a variety of learning contexts in order to build systems that can respond appropriately to contextual features. Beale and Lonsdale (2004), for example, present a hierarchical description of context that they define as "a *dynamic process with historical dependencies*." This is described as "a set of changing relationships that may be shaped by the history of those relationships".

In summary previous research suggests that a context can be described as: a situation defined through the relationships and interactions between the elements within that situation over time. More specifically, in the case of a learner's context we can describe it as a situation defined through social interactions that are themselves historically situated and culturally idiosyncratic. It is also evident that getting the context right can lead to better learning experiences.

The educational research we cite has been influenced by a sociocultural approach and it is worth pausing for a moment to reflect upon the parallels between the recent work on context and the earlier work of writers such as Vygotsky (Vygotsky, 1978; Vygotsky, 1986). Recent work on context has moved beyond the notion of context as a snapshot of elements interacting within a situation and has placed an emphasis upon the importance of the history of those interactions and relationships within that situation. In other words context has both a static and a dynamic dimension in which the nature of the dynamic interactions changes the nature of the static definition. This mirrors the definition of the Zone of Proximal Development by Vgotsky. On the one hand it is a spatial metaphor for measuring a child's potential ability through articulation of the difference between what she can achieve alone and what she can achieve with assistance (Vygotsky, 1986). On the other it is a dynamic process that must be created through socials interactions between the learner and others using sign systems within a culture that are both a means of storing past and of forming future activity (Vygotsky, 1987).

In the introduction to this paper we state that the issue at the heart of this paper is how we can understand context in a way that will enable us to use mobile technology effectively to help learners (and teachers, peers and parents) to adapt the resources they find within a particular context to best support their learning needs. The focus of this paper is therefore the presentation and evaluation of a framework for the characterization of a learning context. In particular, we identify some of the aspects of context should be taken into account, and possibly represented and modelled. Successful evaluation of this framework as a characterisation of a learning context may then inform the future design of experiences that use such technology.

We define a learning context as an *Ecology of Resources*: a set of inter-related resource elements, the interactions between which provide a particular context. In keeping with our previous discussions, both here and in Luckin (2005), this definition has both a static dimension, through which the resources can be identified and categorized, and a dynamic dimension that describes the *organizing activities* that activate the resources and form an

Ecology that is centred on the learner. The categories in the static dimension are: what is to be learnt (Content), how it is to be learnt (Process) and where it is to be learnt (Place.) These are described more fully in Table 1. The organising activities are described in Table 2.

Table 1 Categories of Resource that form a Learning Context

CONTENT - THE STUFF TO BE LEARNT	
KNOWLEDGE -	CURRICULUM -
a) Intellectual/scientific/formal - accepted beliefs about what knowledge/expertise is in a particular subject. Abstract and often very decontextualised b) Tacit knowledge - more obvious in craft contexts such as chef training and guild-based approaches. Usually contextualized which can lead to problems or restrictions whereby master and learner can only operate within a limited contextual sphere. c) Meta - Knowledge	A way of structuring the knowledge to form a subset of knowledge organized in a particular sort of way to meet an intermediate/ particular purpose. For example, an exam syllabus. The point of the curriculum is to formalize the learning. More applicable to scientific knowledge than tacit knowledge. Can be used to ensure that areas of a subject are covered in similar breadth and depth across institutions and that outcomes can be compared across peer groups.
PROCESS - WAYS THAT STUFF CAN BE LEARNT	
TOOLS / MEDIATIONAL MEANS -	
ways for learners to make contact and connect with knowledge and/or perform skills. a) physical tools such as a paintbrush or a sensor for collecting data. b) semiotic/psychological tools such as language Computing technology can be physical and involve communication through language.	PEOPLE who know more about X or how to do X than the learner. Can build relationships between resources to animate them for the learner. Vast range of interaction possibilities: a student reading a text could be considered to be interacting with the author of that text; a learner and teacher or more able peer could be involved in a one-to-one interaction, a group of peers could be learning together, or a small group of apprentices could be learning their skills from a master.
PLACES IN WHICH LEARNING CAN TAKE PLACE	
LOCATION -	ORGANISATION/ADMINISTRATION OF THE LOCATION -
physical environment/location and its components such as desks and tables or trees and shrubs. Particular issues of importance for the use of technology include the availability of power, the existence of glare from sunlight or	May include time as well as space constraints e.g. lesson length. Technology affords possibilities for circumventing organization, e.g. through virtual locations and

strip light or wet weather affecting safety.	networked communication that transcend space and time.

Table 2 Organising activities

á The representation and communication of the teacher/expert/more able peer's situation definition;

á The representation and communication of each learner's situation definition;

á A means of making the situation definition representation accessible to the learner, other people and devices within and beyond a single location;

á A means to identify and represent the range of qualities and quantities of assistance that can be made available to the learner;

á The provision of mechanisms through which individuals can communicate and negotiate;

á Assistance to support participants to collaborate in their formulation of a shared situation definition (scaffolding);

á A mechanism to ensure that assistance is targeted to the learner's needs;

á The provision and allocation of resources to accomplish tasks.

In our previous theoretical discussions (Luckin, 2005) we offer more detailed descriptions of these activities and suggest that the organization of learning resources within the learning context must promote the mutual construction of learning activities between teachers and learners. In some situations teachers or more able peers are likely to play a more dominant role in this process, but nevertheless, the organization of resources must maximize the opportunities for interaction between more and less able participants. It is also important to note that there are additional factors that influence the nature of any context. For example, the culture, as well as the political and policymaking infrastructure within which a context exists, will be defining factors upon its specification and upon the resources that it comprises.

3 Two Case Studies

Here we present two case studies to exemplify the framework in use. These studies illustrate the ways in which technology can link different resource elements within and across learning contexts. Each of the case study was a part of a larger project; here we concentrate only on those aspects of the work that relate to learning context. Both of the case studies presented here used a screen based mobile computing device (sometimes with other additional screen and non-screen based technologies) to enable learners to link learning episodes across multiple locations. For the development of the devices we adopted a Human Centred Design Methodology and were informed by a constructivist, sociocultural view of learning. Concentrating on technology and how it can link resource elements within and across contexts or locations limits our discussion of context to those resources that involve the use of technology. This is of course only a small part of the picture, but understanding more about this limited sub-set of a learning context will help us to develop the framework for subsequent expansion.

3.1 Case Study 1: e-Science

Case study 1 involved secondary school children (aged 13 to 16) completing scientific enquiry activities using mobile carbon monoxide (CO) sensing devices, visualization software and video recording equipment. These learners used the technology on location in the field and within the school classroom. The aim of the work, which was drawn from two related e-science projects, was to explore the use of technology to stimulate students to develop scientific enquiry skills. These skills include planning an experimental study; articulating and testing hypotheses; reviewing results and communicating findings to others as well as thinking about how technology can support scientific research and learning. All students worked in small groups of between 2 - 4 accompanied by a facilitator (teacher or researcher). These groups worked in outside locations around their classrooms to explore and collect local CO and wind-speed readings using a 'tea tray' device (so called because of the way the equipment looked) and anemometers. They made video recordings and logged readings manually with pen and paper for wind readings and automatically for CO levels and position (logged every second). Later in the classroom students reflected on their experiences and on 3D visualizations of the locations which they had explored overlaid with the CO data they had collected. They were encouraged to form hypotheses about why there were variations in their readings in certain locations and to discuss their ideas and the similarities and differences in their data with scientists in the field in London and Antarctica using Instant Messenger.

3.2 Case study 2: HOMEWORK

This case study involved primary school aged children (aged 5 to 7 years) learning maths using tablet PCs in the school classroom and at home. The aimed of the project was to develop a system that enables teachers to plan and build lessons and homework from a selection of suitable multimedia resources for use in the school and home. It also aimed to help parents to support their children with their homework and to strengthen home - school links so that teachers and parents could see what children have done at home and at school. The data discussed here came from studies, initially in the home context and then in a school classroom. 37 family members of children, drawn from two local schools, were involved in the home context study. They completed a diary in which they recorded their family availability and enthusiasm for homework activities involving the tablet PC in the home. Subsequently, 12 sets of parents from the same families took part in interviews in which they were asked about their child's current homework pattern and their attitude to the idea of using a tablet PC for homework. The results from these studies were used to inform the design of the tablet PC interface for homework activities. The tablets and software were then offered to a class of children at one of the schools. The technology used for this project was an Interactive Whiteboard in the classroom and a set of tablet PCs for use in the home and classroom. There was multimedia content that could be launched from either of these devices.

4 The Resource Components in the Case Study Contexts

The *Ecology of Resources* framework in Table 1 offers a categorization of learning context component resources. Table 3 illustrates the nature of the resources available in each of the case study learning contexts. The cultural infrastructure for all the projects was that of the UK formal educational system but the individual secondary school and primary school institutions studied all had their own unique cultures within this over arching infrastructure. We have already suggested that the way in which links are built between resources offers one route to understanding more about the affordances of a learning context. Table 4 therefore presents information about some of the ways in which the learning resource elements in the case studies were linked and in particular the role played by the mobile technology and the people.

Table 3 Case Study Context Resource Elements[1]

ELEMENTS	ESCIENCE	HOMEWORK
KNOWLEDGE& SKILLS		
Knowledge	Formal: ENVIRONMENTAL SCIENCE	Formal: MATHS
Curriculum	Formal: UK GCSE syllabus (age 13 - 16 years) and Informal: scientific enquiry skills	Formal : UK Keystage 1 (age 5 - 7 years) National Curriculum
LEARNING PROCESS		
Tools	Physical: books, pen, paper, digital: hardware (desktop & mobile), software applications Psychological: Language	
	Physical data logging tools e.g. wind meter Mobile Technology only used by learners during the science session. Exercise conducted with a configurable suite of devices distributed across participants which meant that no one person had the whole view of the 'data/device context'	Classroom tools such as counting sticks. Mobile Technology available 24 hours during the study period and personal to the learner.
People	Peers and teachers (researchers) working in small groups - peers, with facilitator.	Peers, teachers, researchers & the learner's family
ENVIRONMENT		
Location	Classroom with standard desks, chairs, board etc. Outdoor study location: trees, roads, parkland, buildings.	Classroom with standard desks, chairs, board etc. Mobile technology wherever learner went. Study focus was on home context.
Organisation	Timetabled sessions in classroom and on location.	Timetabled session in classroom, teacher specifies resources and activities for outside class. Family specify Home organization.

Table 4 Linking Resource Elements using Technology

ESCIENCE	HOMEWORK
LINKS between LEARNERS and RESOURCES	
Multiple units of Mobile Technology used to collect data and prompt scientific enquiry activities e.g. collaborative hypothesis formation in situ. Results of data collection sessions reflected upon in classroom to support further scientific enquiry activities. LEARNER TO PEOPLE LEARNER TO KNOWLEDGE. LEARNER TO LOCATION.	Mobile Technology used in classroom for individual activities as part of session that included other resources including interactive whiteboard. Mobile technology outside school for homework activities and other activities available on tablet PC (no network access). LEARNER TO KNOWLEDGE. PEOPLE TO PEOPLE LEARNER TO LOCATION
PRIMARY CONTROL OF RESOURCE ELEMENT LINKING AND ORGANIZATION	
Teacher within constraints of institutional and syllabus framework. Learners have some choice within learning session and can organize local resources according to their needs. *Learner* determines use of technology with guidance from teacher.	*Teacher* within constraints of institutional and National Curriculum framework. Learners have limited choice within classroom sessions. Teacher specifies homework activities; learners and family members can select other activities. *Teacher* determines use of all technology in classroom *Learner and/or family member* determine use technology in home.

4.1 Data Collection

Working across multiple contexts presents significant challenges to the design of empirical data collection. The technology itself allows us to log and track user interactions, yet this can lead to the collection of vast amounts of data and makes the selection of appropriate analytical tools important. For both case studies we collected a range of data as is summarized in Table 5. In this table we link the data sources to the ways in which the technology was designed to link resources.

Table 5 Linking Resource Elements using Technology: Data Collection

ESCIENCE	HOMEWORK
LEARNER TO PEOPLE. Session video data collection and class reflection. LEARNER TO KNOWLEDGE & LOCATION. Logged CO and GPS data (digitally recorded).	LEARNER TO KNOWLEDGE. Software logs for Tablet PC usage at school and in the home. Teacher Interview audio.

Wind readings (manual recording) Work completed by students including annotated data graphs.	Videotapes & Classroom Researcher notes PEOPLE TO PEOPLE Home: Completed diaries. Interview audio recordings. Completed parental Questionnaires. LEARNER TO LOCATION Home: Completed diaries. Interview audio recordings.

5 Learning from the Case Studies

There is insufficient space here to discuss the cases studies themselves in detail or the extensive data analyses that are (still) taking place. The framework we have outlined is described at a high level and so our aim here is to pull out those findings from the case studies that are relevant to the development of the *Ecology of Resources* framework at that high level. We concentrate on an analysis that can inform the way in which we deploy mobile educational technology so that it can be used to link resources in the most effective and productive manner. We categorise the results according to the links we identify for each project in Tables 4 and 5:

- Linking Learner to People
- Linking Learner to Knowledge
- Linking Learner to Knowledge and Location
- Linking Learner to Location and its Organization
- Linking People to People

These links are created through organising activities as described in Table 2, such as mechanisms through which individuals can communicate and negotiate. On occasions, discussion of results also includes the analytical techniques we have adopted in order to help us pull together multiple data sources.

5.1 Case Study 1: e-Science

The e-Science case study demonstrates the benefits and challenges that arise from our ability to collect data about a learner's interactions across multiple locations and over different time frames. One of the challenges for analysing such data is pulling enough information together from the multiple data sources to understand the larger picture of the activities in which learners engage. In order to achieve this with the e-science data we constructed activity maps that identify in the data the characteristics and organizing activities from the *Ecology of Resources* framework (see Figure 1. The word *activity* here is being used in its general descriptive sense and is not a reference to Activity theory). For example, we represent the physical location, the people and the tools that are available and the activities they complete, such as communication and hypothesis formation.

Creation of the maps required charting the learners' interactions with each other and with the data-logging devices. Interactions were categorised to explore the nature of the scientific activities they took part in and the ideas generated whilst using particular types of technology. Aspects noted on the maps included: a breakdown of the type of comments made by each person within the group (including facilitator) and different co-operative and collaborative behaviours, e.g. suggesting where to test for CO or communicating readings to the group. The maps provided overviews that we used to determine patterns and trends in the behaviour of participants. These enabled us to build a picture of the roles played by the different resources, both participants and technological artefacts, in each of the learning situations we investigated. More information about the activity mapping technique can be found in [Avramides, Smith, Luckin & Fitzpatrick (2005)].

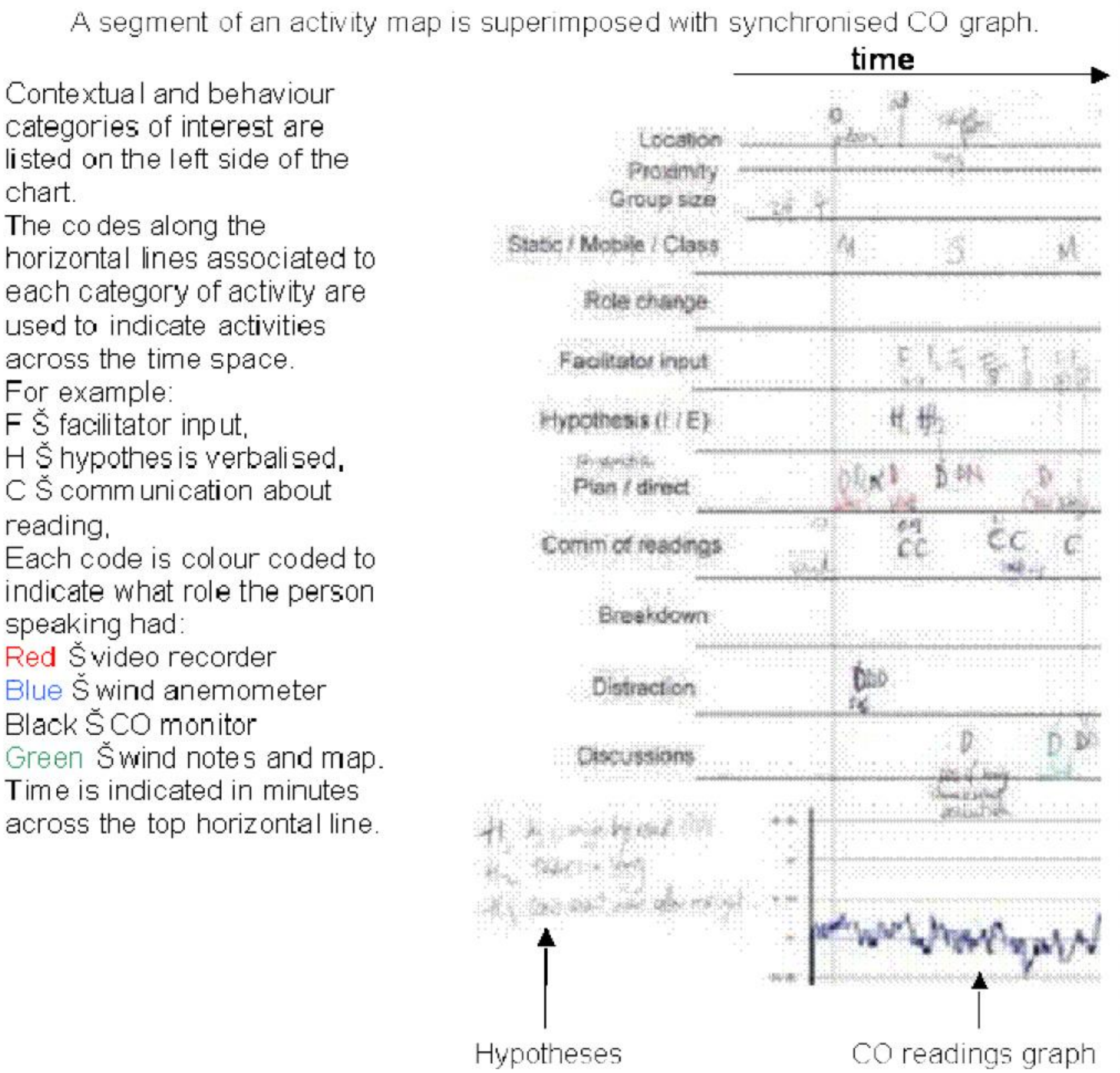

Figure 1 Example of an Activity Map

A segment of an activity map is shown in Figure 1, it is superimposed with the CO readings graph, synchronised, at the bottom. In this example, after an initial distraction the group start to take CO readings, some of which are communicated by the person logging the CO levels with the tea-tray device to the rest of the group. An initial hypothesis is formulated: that there will be a big change in CO levels when the group reaches the road, and the facilitator initiates a discussion during which subsequent hypotheses are formulated. The person operating the video camera plays a leading role in formulating the plan and directing activity. All in all three hypotheses are discussed by the students and their facilitator during this segment of activity:

1 - There'll be a big change [in CO] when we get to the road

2 - There's a lorry [it is coming our way and provides an opportunity to test it]

3 - Cars emit more [CO] after a red light as they accelerate away

Linking Learner to People

The session described in Figure 1 is representative of our findings. Our analysis indicates that each device's functionality and physical attributes afforded a different way of interacting with it. For example, the person holding the 'tea tray' played a key role since the user-interface of the 'tea tray' was only visible to the person holding it and, therefore, the group had to rely on that person to communicate the CO values. Engagement with the device was high, but there were also breakdowns. For example, when the student holding the tea tray was distracted (or was shy) and did not verbalise changes to CO levels detected. The camera person (more than the other roles) was likely to be distracted away from their task of filming by other peers, workmen, teachers and members of the public.

From this we can conclude that the facilitator role was important for collaboration and engaging learners in scientific enquiry - in shaping group interactions during the data collection sessions by engaging the group and encouraging critical thinking e.g. prompting for CO and wind readings; for hypotheses to explain CO readings; for proposing locations where CO levels would be high; and encouraging students to contrast with previous places visited. We can conclude that learners need to be reminded to vocalize information regularly with peers. This could inform the future development of the technology through the design of prompts to scaffold appropriate facilitator input e.g. via PDA using a suggested question for group discussion, triggered by location, incorporating current data-logged values.

Linking Learner to Knowledge and Location

From our findings we have gained an increased understanding of what needs to be done to facilitate learning around such technologies. The trade-offs between a controllable interface versus accurate data logging need consideration, likewise, the use of larger screens and audio displays to allow all group members to be aware of data readings, or the activity being completed. It is also important to provide an opportunity for all learners whatever their role to narrate their thoughts into a recording device, not just the camera person or person closest to the camera at the time (who maybe talking about non-related information). These recordings can then be used later to create annotations in the visualization tool. With respect to the design of information, the provision of trend data particularly for variable data such as wind readings needs to be considered.

This brief summary of some of our e-Science work illustrates the way in which the activity maps can re-construct a particular context through interrogation and representation of data about the interactions between people, their role, the devices, and the physical attributes of the location. These maps support the evaluation of the mobile technologies as resources within a broader context of people and location. By attending to context in this manner we gain valuable information about the future design and deployment of such technologies.

5.2 Case study 2: HOMEWORK

One of the key themes for the HOMEWORK project is to understand how best to link the experiences that a learner has in school with those she experiences at home. One of the ways in which we are trying to achieve this is through the variations we allow in our learner model in recognition of a learner's current location. For example, we have fields within the learner model for her language ability and level of confidence and we recognize that these may vary between the school and the home context. However, here we concentrate upon our work to develop a software interface for home use.

5.2.1 Exploring the resources available in the home

Linking Learner to Location and its Organization: the Home

Here our analysis looks at the home context before introduction of technology to inform the introduction of that technology. We wanted to know about the way homework was completed, where it was done, with whom and at what time. Previous work conducted by Kerawalla and Crook (2005, for example) on the use of educational CD-ROMS in the home found that children generally use these products alone, usually in a room separate from the main activities of the house with poor collaboration from other family members. To an extent the portability of the tablets may help overcome this problem. However, Kerawalla and Crook also found that parents did not know how to support their children, nor did they feel they knew what happened at school. The data we discuss here are the diaries completed by parents and the audio transcripts of interviews with parents, which were transcribed and coded. There was some variance between the two schools, but there was general agreement that the best time for doing homework was on weekdays during the hour immediately after children return from school. At this time parents reported high availability and energy with a fall-off after 7pm. Homework activity is quite formalized with work that requires writing always being done sitting at a table.

Linking People to People

All parents/carers wanted to help their children with homework to some extent. The kinds of activities they included in this were: helping their child to understand the task, offering general encouragement, doing the task for them, and even leaving them alone. Parents identified a wide range of home-school links. These included: parents going into school to help, being school governors, and filling in reading record books.

All parents wanted to know more about how their child was progressing and what methods were being used to teach them so that they could help at home. They think teachers are too busy and are only to be visited when there is a problem. Although, in fact, they may not know very quickly when there is a problem. All parents were keen on the idea of their child having a tablet PC for homework in particular they were interested in being able to find out what their child had done previously at school. For example, one parent commented "this [tablet] is wonderful from that point of view because it means that we know what he's actually doing. I tend not to speak to his teacher unless there's a problem."

As designers we can conclude that the home activities we offer within the HOMEWORK system must therefore be flexible enough to meet the needs of a diversity of home school link arrangements.

5.2.2 Designing an interface for the Home

We used the data collected in the home context to develop an interface for use of our software for homework as pictured in Figure 2. Here we discuss findings from our initial study using this interface.

Linking Learner to Knowledge and Location

Here we discuss the data collected via logging activities on the tablet PC and a questionnaire for parents, also on the tablet PC. Analysis of this data gives us insight into what functionality was used, when it was used and, from the completed diaries, where and with whom. The log data illustrates that 100% of children and/or their parents used the 'This week at school' functionality and launched one or more pieces of the linked content. 93% of them also used the 'This week at home' function and all of these users launched one or more pieces of the associated content. 75% also used the 'My history' function, although few of these parents actually launched activities.

Linking People to People

From the 29 diaries completed by parents, carers or family members we learnt that both children and parents enjoyed using the tablets at home, using words such as "fun", "like", "love", enjoy". Parents were positive about collaborating with their child to help them with homework. The negative comments were mainly about the usability of the tablets.

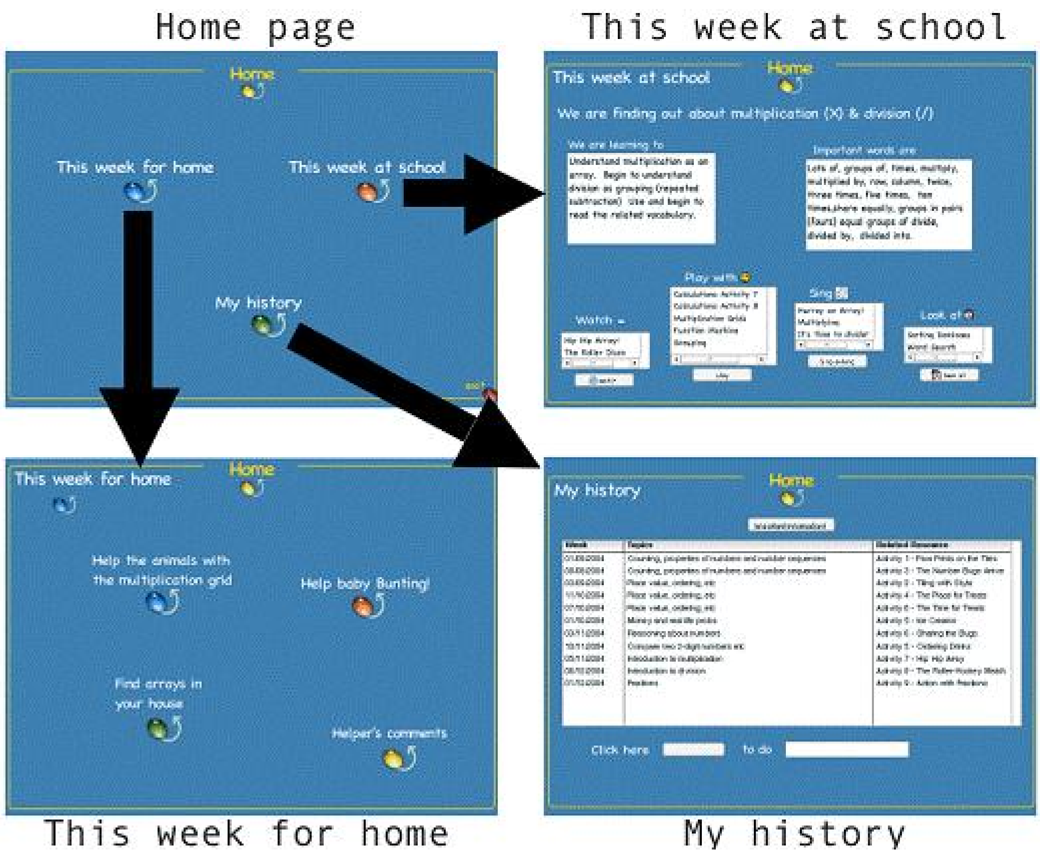

Figure 2: Homework Home interface

From this we can conclude that we found consistency between what parents stated they would like from technology and what they then used when it was offered to them. In a later study over a longer period of time one parent commented that the HOMEWORK software meant that her daughter was able to show her "it's what she's been doing at school, so it sort of followed on - she's doing the same at home. So it's not seen as, this is homework and that's schoolwork, it's sort of there's more of a flow from one to the other." Once again suggesting that the key to providing continuity between experience at school and home is through appropriate contextualization of the activities to be done at home with those already completed at school, not merely the provision of mobile technology.

This confirms the importance of understanding the context into which technology is to be introduced before completing the specification for its deployment. Even though this may be demanding, the differences between schools and homes even within a small geographical area illustrates that technology needs to be flexible, possibly more flexible than is currently realistic. This also offers further evidence to support the need for limited functionality and carefully focused activities.

6 Discussion and Conclusion

We have presented an educational context as an *Ecology of Resources* that can be deployed in a learner centric manner enabled by organizing activities. As we stated at the start of this paper our motivation is to understand more about the development of educational experiences supported by mobile technology to enable learners (and teachers, peers and parents) to adapt the resources at their disposal within a particular context to best support their learning needs.

Different locations will be more or less adaptable, however the smart use of technology can maximize the amount of assistance that the learner can glean from her environment and ensure that it is targeted at her ZPD. We have used our description of an educational context to discuss two case studies in order to validate it as a framework for evaluation and design.

The e-Science case study demonstrated the benefits and challenges that arise from our ability to collect data about a learner's interactions across multiple locations. The activity maps we constructed combine the characteristics from our context framework with the organizing activities that need to be supported. For example, we represent the physical location, the people and the tools that are available along with the activities they complete, such as communication and hypothesis formation. We identified the ways in which the different tools required learners to adopt particular roles to access the information resources within a context, and particular means of communication in order to access each other's knowledge and understanding. Our findings conform with the presentation of a context as an *Ecology* where resources need to work in harmony to achieve balance. We saw the value of learners using technology to access information about a particular location both whilst in it and also when back in the classroom and through that to take part in scientific hypothesis formation activities.

From the HOMEWORK case study we see the value of conducting context analysis with the people who will be interacting with the technology that is to be developed for use in that context. This work also highlighted the variation in parental attitudes, aspirations and home contexts between different schools even within a small geographical area and socio-economic group. Technology must therefore be cast in the role of helping to identify ways in which resources can be adapted to meet the needs of a learner rather than as a tool that can adapt itself to the context and to the learner. It must also be used as a means to provide continuity across locations: the appropriate contextualization of activities across school and home contexts is a key design principle. Both projects identify the need for technology to offer limited functionality and carefully focused activities.

The *Ecology of Resources* framework as we have presented it is still relatively high level. It consists of a description of the categories of resource elements that constitute a context and the organizing activities that activate these resources to form an *Ecology of Resources* centred around the learner. This approach has the advantage of encompassing a wide range of context types, and has proved useful in our analysis of the case studies. It does however need further specification to provide a 'richer' description of context. This richer description should yield an ontology for describing educational contexts. Such an ontology could then be used in educational technology design, for example to help link learner and context modeling through a common set of descriptors. At the moment we have talked in terms of the learner, her situation definition, ZPD and need for collaborative assistance. We have not gone into further detail about what we need to know about her emotions and motivations for example. This is currently encompassed within the learner modelling work we are currently undertaking, but is beyond the scope of this paper.

The organizing activities and ecological metaphor we have adopted also needs further specification so that we can start to identify the inter-relationships that can lead to balance. We may be able to identify changes in a particular resource element or activity that will lead to perturbations in other parts of the ecology of the learning context. This is future work that will require further analysis across a wider range of learning contexts than that we have tackled here if we are to develop a comprehensive framework for the design and evaluation of all forms of educational technology

Our approach is in contrast to the approach adopted by the Ubiquitous Computing community. Our emphasis is not for the development of context awareness within the technology itself, other than at some basic level of operation. Rather we would promote the explication of learner and contextual data so that it can be used by teachers and learners to select those resource elements that are best suited to a learner's needs.

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[1] Each learner has a device for their use, but devices were only personal to the learners for the duration of the study therefore the extent to which learners may have felt the devices to be their own was limited.