The learner centric ecology of resources: A framework for using technology to scaffold learning

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The Learner Centric Ecology of Resources:
a Framework for using Technology to Scaffold Learning.

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Abstract This paper is based upon a Keynote presentation at CAL07 and extends previous introductory descriptions of the Ecology of Resources model of educational contexts. The relationships between the elements in the Ecology of Resources are a particular focus for discussion here. In particular, we consider how we might use the Ecology of Resources model to scaffold learning so that a wide range of the resources available to a learner within their context can be used to best support their learning needs. Resources here include people, technologies and artifacts. We look for ways in which they can be linked and marshaled in a learner centric manner and draw on the HOMEWORK and VeSel projects as a practical examples of the way the Ecology of Resources framework can be used.

Keywords collaborative learning; improving classroom teaching; interactive learning environments; pedagogical issues; teaching/learning strategies.

Introduction

In this paper a framework for evaluating and designing educational technology called the Ecology of Resources is discussed. This discussion builds upon previous work that introduced the idea that an educational context could usefully be described as a "Learner Centric Ecology of Resources" (Luckin, du Boulay, Smith, Underwood, Fitzpatrick, Holmberg, Kerawalla, Tunley, Brewster and Pearce, 2005; and Luckin, 2006). Resources that can be deployed variously but that should promote and support various mediations, including those of the teacher and learner.

The current paper takes the suggestion a step further. It considers the relationships that can exist between the elements that make up the Ecology of Resources within a particular context and the way in which such a context can become a *Learner Centric Ecology of Resources*. An initial discussion of the theory that grounds the Ecology of Resources Model is followed by an explanation of the elements and relationships that make up the Learner Centric Ecology of Resources Model of Context. The value that the model might bring to evaluation, design and theory development is considered and some future directions are identified.

Background: Vygotsky, Learning, Scaffolding and Technology

The Learner Centric Ecology of Resources Model is inspired by Vygotsky's sociocultural philosophy (Vygotsky, 1978, 1986). This identifies the important relationship between a learner's context and the learning that occurs as a result of her interactions within that context. Both the teaching and learning processes are encompassed within the Russian term "obuchenie" used by Vygotsky. The inseparability of these two processes is then highlighted through the emphasis that Vygotsky places upon interaction between a learner and her environment. The development of the individual is the result of her internalisation of these interactions with her environment. This internalisation process has been referred to as the "decontextualization of mediational means" (Wertsch, 1985).

Vygotsky addressed the issue of internalisation when he proposed the Zone of Proximal Development (ZPD) as the essential 'ingredient' in effective *obuchenie* (Vygotsky, 1986). The ZPD has two aspects, firstly, it is a measure of the child's potential ability (Vygotsky, 1986) and secondly it is something that must be created by the interactions that form the child's learning experience (Vygotsky, 1987). The ZPD requires that a learner works in collaboration with a more able partner. The need for this more able partner arises from the belief that the activities that form a part of the child's education must be beyond the range of her independent ability. The more able partner therefore needs to provide appropriately challenging activities and the right quantity and quality of assistance. The learner can then be inducted into the culture of her society and empowered as an autonomous learner (Becker and Varelas, 1995).

One way in which the ZPD and the timely interventions it requires from a more able partner have been used in teaching is in *scaffolding* (Wood, Bruner and Ross, 1976). Scaffolding is a term used to describe tutorial assistance. Effective scaffolding is presented as something more than the provision of hints and graded help. It involves simplification of the learner's role and is described as enabling interactions in which learners and their more able partners achieve success on a task but that "the nature of their individual contributions varied with the child's level of ability" (Wood, 1980). The more able partner in this collaborative relationship needs to organise the child's activity in a way that prevents her being overwhelmed by uncertainty. The model of effective teaching proposed by Wood involves the use of the contingent teaching strategy, which requires the more able partner to adopt the following approach:

> When the child makes an error, then immediately take over more control......However, if the child is successful in following instruction relinquish some control.
>
> (Wood and Middleton, 1975 page 286)

The contingent instructor provides advice at one level above the child's current level of success. This is described as the "success-failure boundary or the child's 'region of sensitivity' to instruction" (Wood, Wood and Middleton, 1978).

Scaffolding has been successfully employed within the design of educational technology to help bridge this recognition-production gap between what learners want to achieve and what they are able to effect themselves without assistance. Successful scaffolding requires collaboration or assistance for a learner or group of learners from teachers or other more able partners who must provide appropriately challenging activities accompanied by the right quantity and quality of assistance. In order to provide such appropriately challenging activities and sensitive assistance, teachers and peers need to know something about their learners' current understanding of the subject matter being learnt. For technology to provide software scaffolding the system needs to maintain a model of its learners. Systems that do precisely this have been developed and provide one way to use the ZPD to inform educational software design (see Aleven, McLaren, Roll, & Koedinger, 2004; Rebolledo, du Boulay, & Luckin, 2005 for example).

However, the proliferation of ubiquitous and pervasive technologies requires that we now look beyond scaffolding within software and the resources that it might make available to teachers and learners. We need to consider the wider world of resources beyond the desktop and investigate how their use might be informed by the ZPD. This need was the motivation for the Ecology of Resources, which was born out of the ZPD and two additional constructs: *The Zone of Available Assistance (ZAA) and the Zone of Proximal Adjustment (ZPA)*. The ZAA and ZPA were introduced in order to try and clarify the relationship between the ZPD and educational technology (Luckin, 1998, 2006). The ZAA is used to describe the types of resources, both human and artifact, that are available within a particular context to help a more able partner to offer appropriate assistance to a less able learner. The ZPA represents a selected subset of the ZAA that are the resources that are the most appropriate form of assistance for a given learner at a particular moment in time. The existence of a rich set of resources within the ZAA is not sufficient to ensure the interactions necessary to create a ZPD for the learner. As well as being a resource themselves, the more able partner is also responsible for ensuring that the resources available within a particular environment are organized and activated appropriately for that learner to form a ZPA. This may simply mean making obvious to the learner the forms of assistance that already exist within her environment or finding a way to represent the learners' needs so that she and the other stakeholders in the process of her learning can select appropriately.

Background: Models of Learners, Context

The argument presented in this paper is that we need a framework that helps us design educational experiences that match the available resources to each learner's needs. There exists much previous research from a variety of disciplines that is relevant to this enterprise. For example, there is the scaffolding work introduced earlier that has looked at the development of adaptive and adaptable software that models a learner's progress and attempts to offer individually sensitive scaffolding assistance (Jackson, Krajcik, & Soloway, 1998 and Koedinger, Anderson, Hadley, & Mark, 1997 , for example). There is also work that considers the nature of learning and the design of educational activities and institutions such as Mercer (1992) and Wood, Underwood and Avis (1999). Plus work that has resulted in the development of appropriate interfaces for pervasive and ubiquitous computing technology; and work that has explored the nature of context and the design of context sensitive technologies (Dey, 2001, Dourish, 2004 and Chalmers, 2004, for example). The Artificial Intelligence in Education research community has started to explore how both learner and context modeling might be combined for the design of adaptive desktop technology that takes a learner's context and potential collaborators into account (Greer, McCalla, Vassileva, Deters, Bull & Kettel, 2001). And those exploring mobile learning have developed an interactional model of context and a hierarchical description of context as "a set of changing relationships that may be shaped by the history of those relationships" (Beale & Lonsdale, 2004).

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 Learner Centric Ecology of Resources Model of Context

The Learner Centric Ecology of Resources Model of Context attempts to pull together this previous work and the theoretical underpinnings of the ZPD, ZAA and ZPA as we consider a learning context as an *Ecology of Resources: a set of inter-related resource elements, including people and objects, the interactions between which provide a particular context*.

The learner is the starting point for our Ecology. In an educational situation there will also be some 'stuff', *Skills* or *Knowledge* that our learner needs to learn about and some resources that might help this learner learn that 'stuff'. These *Resources* might be books, pen and paper, technology and other people who know more about the 'stuff' that is to be learnt. However, the 'stuff' to be learnt is usually filtered through some kind of organisation or *Curriculum* and has been subject to a process of validation. This filter is stronger for subjects such as maths and other formal educational enterprise than for more grounded skills such as motor mechanics or plumbing. However, even with skills based subjects there is still, to some extent at least, some formalisation of what is recognised as the accepted view about the knowledge and skills that need to be mastered. Likewise the resources that may be available to the learner are organised in some way. We use the word *Administration* to convey that here. This *Administration* forms a filter in terms of a learners' access to at least some of the resources that might be available to help them learn. There is a relationship between the nature of the stuff to be learnt; the skills and knowledge and the nature of the resources that might be useful to the learning process. For example different tools will be needed for a motor mechanics course and a different teacher to those required for a psychology course. This relationship is two-way. In addition, there is also a link between the way in which a particular body of knowledge is organized, or its curriculum, and the administration of the available resources, a library for example. As with the relationship between knowledge and resources, this relationship between curriculum and administration is two-way. Figure 1 illustrates this situation.

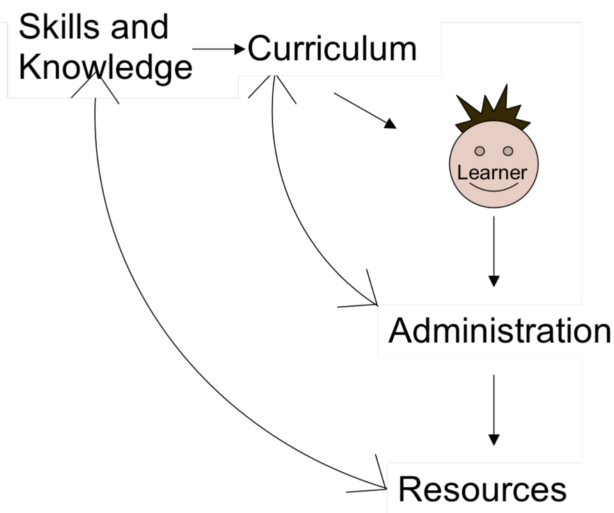


Figure 1 The learner using resources to access knowledge

The original software scaffolding work referred to above is consistent with this model. The software was developed in order to help learners understand a particular set of concepts or skills as organized and recognised by the particular curriculum in force: U.S. Maths for Koedinger et al 1997, and UK Key Stage 2 Science for Luckin, 1998. The resources available through the software were designed with respect to these curricula and were administered by and made available to the learner through a particular interface. The learner could interact with the software through this interface and their activity was recorded and interpreted in accordance with the learner modeling strategy built into the software. The nature of the resources offered to the learner was adapted in accordance with this learner model.

In other words the ZAA was within the software and the scaffolding techniques were used to make *timely interventions* and draw our learner's attention to the assistance and resources available, thus creating a ZPA.

Originally the learner models and interventions created through software scaffolding work related only to the learner's cognition. This approach yielded some interesting results and the software scaffolding community got better at intervening in a helpful fashion and started to try and build models beyond those initial contingencies. These models included models and scaffolding that considered a learner's metacognition, affective and even meta-affective state. This software scaffolding activity meant that a learners' interactions with the software were bi-directional, in other words the learner's activity altered the nature of the software and vice versa. The same cannot be said for a learner's interactions with the subject matter being learnt: it was and largely still is unlikely that their activity will make any difference to the nature of what is accepted as valid subject knowledge or skills.

Software scaffolding has made some good progress with respect to helping learners learn. However, all this has been largely still within the constraints of desktop technology resources. The question that draws our attention in this paper is: *how do we use technology to scaffold learning in a connected world where resources are no longer tied to the desktop?* How do we use technology effectively to link and marshall the most appropriate resources for the learner, whether they are people, software, hardware, books, paper and so on?

In order to progress this agenda we turn now to consideration of what makes up educational contexts and how we might usefully model them. We need to add *Environment* to our model in Figure 1. In doing so we also need to recognize that in the same way that a learner's access to *Knowledge* and *Resources* is mediated by *Curriculum* and *Administration* so too a learners access to the *Environment* is mediated by its *Organisation*. As in the case of knowledge, this organisation is more obvious in formal settings such as schools where timetables and regulations have a strong influence on the ways in which learners interact with their environment. We noted earlier the relationship that exists between the nature of the stuff to be learnt; the skills and knowledge, and the nature of the resources that might be useful to the learning process. This is true for the environment too. For example, formal subject matter is usually taught in schools where the resources are of a particular nature. In addition to which there is a relationship between the organisation of the environment, the administration of its resources and the nature of the subject matter being learnt. We also observed earlier that a learner's activity has little impact upon the nature of knowledge and curricula, likewise they often have little impact upon the organisation of their Environment. Hence in Figure 2, which illustrates this Ecology of Resources approach there are bi-directional arrows linking *Knowledge*, *Resources* and *Environment*, and linking *Curriculum*, *Administration* and *Organisation*. However, the arrows between a learner and her Environment and between a Learner and the Knowledge she seeks are uni-directional.

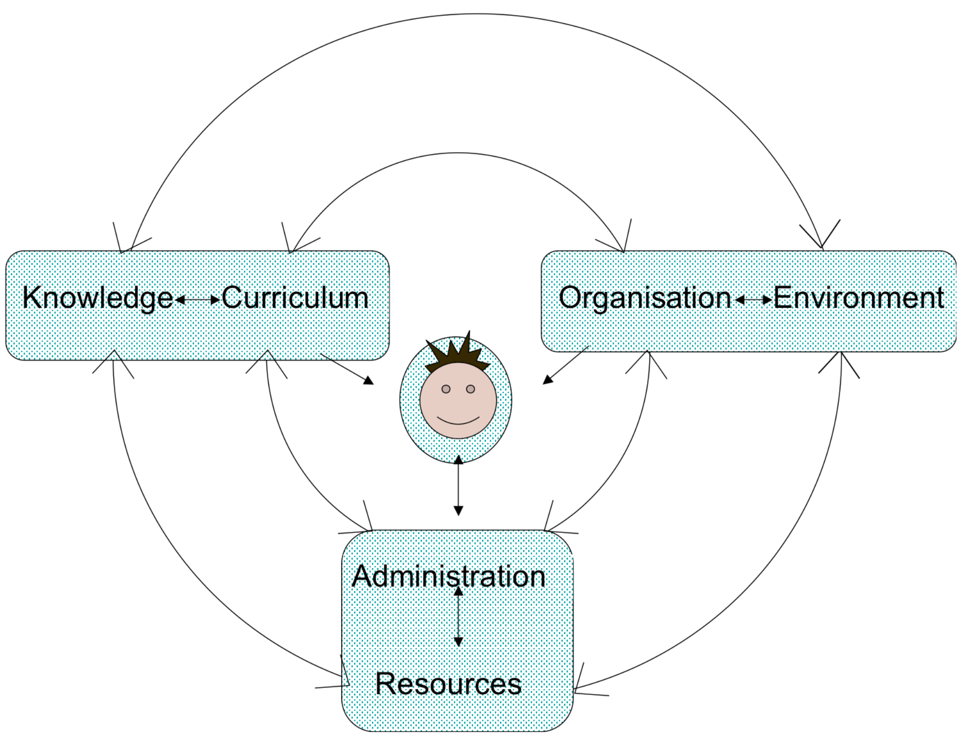


Figure 2 The Learner Centric Ecology of Resources

At this point it is worth noting that this approach is not restricted to a single learner, we could be working with groups of learners at the centre of our Ecology of Resources. It is also important to recognize the needs of other stakeholders such as teachers and parents. They too need to be the centre of an Ecology of Resources that meets their needs. Finally, there is a wider perspective that must be considered. All of the elements in any Ecology of Resources bring with them a history that defines them and the part they play in the wider cultural and political system. Likewise, the individual at the centre of the Ecology of Resources has their own history of experience that impacts upon their interactions with each of the elements in the Ecology. This wider context is represented in Figure 2 by the areas that surround each of the pairs of elements and the learner at the centre. The existence and the importance of this wider cultural perspective can be recognised through the use of participatory methods to develop effective technologies.

But where does this get us with respect to answering our key questions about how we use technology to make links between, and to marshall, the most appropriate resources to scaffold learning? Firstly, the Ecology of Resources might act as a design tool to identify the new contingencies that need to be scaffolded as we try to match models of learners with models of their context. Secondly, it offers us a framework within which we can evaluate existing technology interventions by exploring the extent to which all the relationships depicted in Figure 2 are in place. Thirdly, closer examination of the arrows that connect the learner to the different elements in the Ecology may help us to reconceptualise the learning-teaching process. Each of these three possibilities is explored in a little more detail in the three sections that follow.

The Ecology of Resources as a Design and Evaluation Framework: The Homework project

The Homework project worked closely with parents, teachers, 5-7 year old children and commercial partners to design, develop and evaluate an exemplar interactive educational system. The system was called HOMEWORK and it supported integrated learning across home and school contexts. The software scaffolding work discussed earlier informed the design of the system, which aimed to scaffold learning across multiple contexts and technologies. The idea behind the system was to strengthen home school links by providing a focus around which children and parents could explore together, out of school, recent activities used in class as well as related information aimed at providing parents with greater insight into their child's current learning.

The HOMEWORK system consists of components for lesson planning, control and home use. It contains a rich set of multimedia and associated interactive numeracy resources aimed at helping Key stage 1 children (aged 5 -7 years) learn about maths. Teachers use the software to link these resources together into lesson plans. In the classroom, the interactive whiteboard is used for whole class activities and each child has their own tablet PC for individual and small group activities. The teacher controls classroom activity from her own tablet PC and can allocate new activities or send messages to individuals or groups of children. When planning each lesson the teacher can also decide upon homework activities and allocate them to individual children's tablets as appropriate. After school children take their tablet PC with them and can use it at home or elsewhere, individually or with parents. At home, in addition to homework activity set by the teacher, the tablet provides access to the resources used in class that day and in previous sessions (irrespective of whether the child was actually in school or not) and information for parents about the learning objectives to which these activities relate. There are also links to other relevant fun activities, and a messaging system to support parent and teacher communication. Figure 3 illustrates the interface that provides access at home to homework activities, past work, recent work done at school and fun activities.

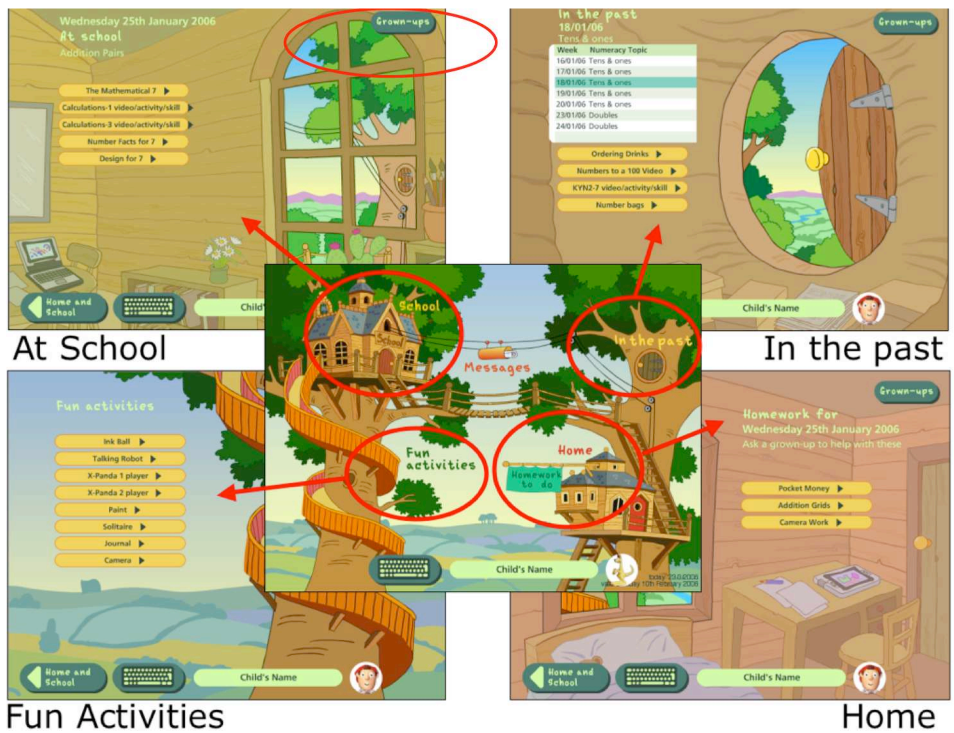


Figure 3 The HOMEWORK system interface on the Tablet PCs when out of school.

The HOMEWORK system was developed iteratively and incrementally. The design process had six phases that involved over 40 teachers from 18 different schools including inner city and rural establishments. More than 80 families were also involved in the design process. The increasingly functional prototype HOMEWORK system was evaluated at several stages, including a 4-week and a 2-week study, involving home and school use of the penultimate and final functional prototype system by more than 30 children from a rural village primary school, their teacher and parents. Multiple data sources that included: Researcher notes, Videotapes of school and home sessions. Logging software output, Parental diaries and face to face interviews, Questionnaires, Teacher interviews and Pre and Post learning tests. Interviews with parents, teachers and researcher observations indicated that children very much enjoyed having their own personal tablet both in the classroom and the home. The logging software evidenced that the tablet PCs were used to complete homework activities, view video, complete the non-homework 'fun activities' and view information about the activities a child had previously completed. The pre-and post system use test results evidenced learning gains.

A small observation study that compared a maths lesson where the HOMEWORK system was used with a maths lesson where the system was not in use revealed that when the HOMEWORK system was used more time was spent on doing maths, with little or no time spent by children waiting for attention. The children also displayed increased attention and engagement in the learning task when using the HOMEWORK system tablet PCs. There was also evidence from the teacher that she had noticed an improvement in some children's mental arithmetic during the trial, as revealed in this quotation from a teacher:

"I've certainly noticed people like [*child's name]* she seems a lot more confident with her mental arithmetic. I don't know if that's as a result of using the tablet at home and in school or whether Mum's been doing extra things with her, I'm not sure."

The UK school organisational context was a relatively 'known quantity'. However, the home organisational context is relatively unknown and far more variable. For example, the organisational context for a learner who is in the car waiting for his sister's ballet lesson to finish is very different to the context where a learner is sitting at home while her mum is making tea. In addition to this, the roles are less stable in the home context. Parents might be conceived of as supplementary teachers but they also become learners in this context. For example, they can learn about their child's curriculum requirements and how to teach maths, also possibly in some cases they may learn basic numeracy. The HOMEWORK system needed to recognise these variations and provide appropriate support. Our early empirical work therefore explored the organization of the home context. Parental diaries and interviews revealed that Homework activity was quite formalized. For example, it was often completed at a table in a family space, rather than the child's bedroom. Parents wanted to help their children, however they needed to be given clear guidance about how to help with homework activities and these activities needed to be designed to encourage parental collaboration. Later when parents were able to use the HOMEWOK system, those who reported having spent increased time working with their child at home also reported increased enjoyment. There was also evidence that parents felt better informed about their child's learning activities and more able to support them as illustrated in this quotation from a parent who took part in the penultimate system evaluation:

"I've got a lot better understanding of what level they were operating at, and the theme of what they're looking at…….if you're giving them their pocket money or things like that… instead of giving them a fifty pence, or something, then you can give them five tens and you can back up and reinforce that message".

The data from teacher interviews indicated that teachers were keen to have lesson planning tools and were willing to spend time on customisation provided the technology was integrated into their normal classroom practice and the constraints of the institutional context were recognised. Teachers were also keen on having a system that would allow them to monitor and control what happens during the lesson, to be able to see clearly where children were up to in their activity. They also very much appreciated being able to offer alternative forms of homework and to strengthen links with the home. This quotation from one of the teachers involved in the final project phases sums up these findings well:

"Yes I think it's great, before I was only able to issue homework that was either worksheet based or activity based or physical where they've brought something in.. the fact that they've got a camera to use, access to videos and activities it's really exciting. It's opened up a link as well between home and school… the parents have been happy that they can see what we do at school as well. It's a good thing."

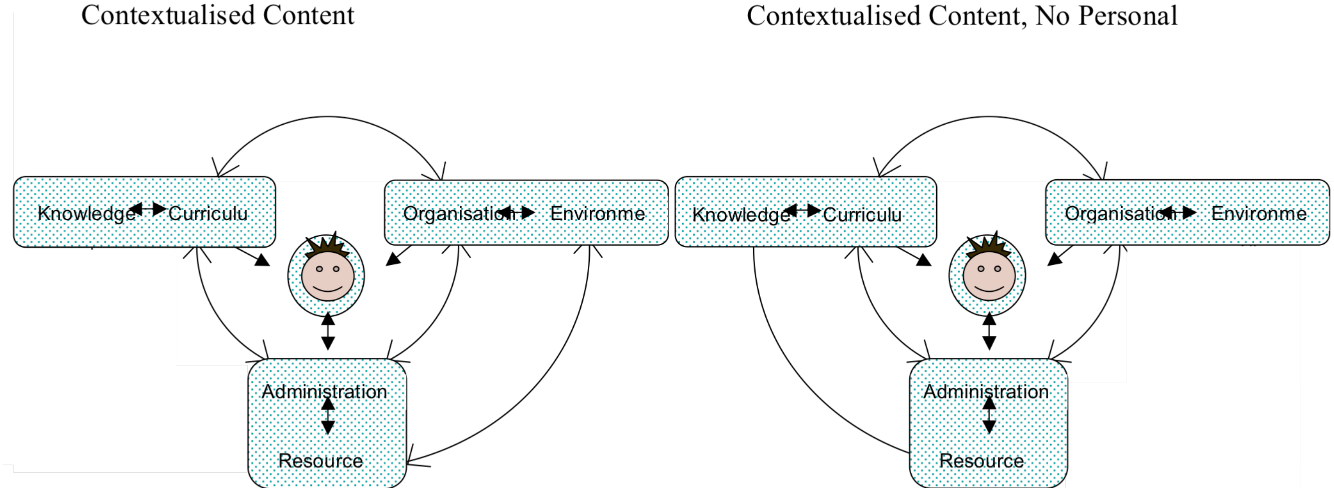
There is insufficient space here to provide more detail of results and analysis, these can be found in Luckin et al 2006, for example. For the purposes of this discussion it is important to note that the empirical studies demonstrated that when designed and used appropriately educational technology could improve links between home and school learning and close the gap between parents, teachers and learners. It should also be noted that the appropriate introduction of technology can undoubtedly change roles and organisational contexts.

We now consider the HOMEWORK system in terms of the Ecology of Resources model from Figure 2. For a small part of the curriculum and a limited range of resources and environments the HOMEWORK system addresses all of the links between the elements in Figure 2. It offers activities that require that the learners engage with the mathematical *knowledge*, concepts and processes considered appropriate by the English National *Curriculum*. These activities are carefully designed to suit the child's *environment* and its *organisation* both at school, at home and in between. The *resources* available to support the child include the technologies of tablet PC and interactive whiteboard, as well as teachers and parents. The activities the child completes use each of these resources in a manner consistent with both their environment and the maths being learnt. The requirements of the activities also recognises that the *administration* of the resources is different at school and at home. In addition to which the tablet PC is largely in the control of the child, is personal to each individual and provides a link across different environments and maths activities. The HOMEWORK system enables the tablet PC to offer the convergence of digital and physical personalisation for each learner; personalisation that is motivated and scaffolded by appropriately contextualised activities and more able others.

This is an interesting comparison to alternative approaches to linking home and school learning through technology. For example, a system that offered each child their own personal device, a laptop for example, but did not provide the interface that links learning across locations or the specifically contextualised activities and associated scaffolding, could result in a situation such as that illustrated in Figure 4a. The resources offered to the learner will include a technology that is personal and that is available across multiple locations; this provides a link between resources and environment. However, without the contextualized activities and integrated interface the technology resource offered to the learner and those who wish to support her may not enable them to relate the knowledge and skills experienced within one location to those experienced in another. Alternatively, if the HOMEWORK interface, activities, personalisation and scaffolding were offered as an on-line system that could be used via a home PC then we risk a situation such as that depicted in Figure 4b. The link between knowledge and skills experienced in the classroom might be linked to those experienced at home through the on-line HOMEWORK system. However, this will be constrained by the learner's access to the home computing technology and unlike the tablet PC or laptop that technology would not be able to be used outside the home environment. The result is that the contextualisation between knowledge and environment will be reduced and the potential for technology to link resources across locations is limited.

Figure 4a Personal Device, No Personal, Contextualised Content

Figure 4b On-Line Personal, Contextualised Content, No Personal



Further case studies that illustrate how the framework might be used for evaluation can be found in Luckin, 2006 and Luckin, du Boulay, Smith, Underwood, Brewster, Fitzpatrick, Holmberg, Kerawalla, Pearce and Tunley, 2005 for example. These works illustrate how the framework can be used in applications of mobile technology in Higher Education and with e-science activities in secondary school education. Luckin, Shurville and Browne (2007) also offers an example drawn from Higher education and illustrates how the Ecology of Resources approach can help when it comes to scaling up solutions and adopting a Participatary Design 'Lite' approach.

The HOMEWORK system example could be considered to reflect a somewhat ideal situation, in which learning takes place in a traditional manner that fits the model quite easily. However, as already discussed, the out of school context is far from fixed and is a relatively unknown quantity. It might also be argued that the HOMEWORK approach yielded positive results simply because it was more labour intensive with extra people, such as parents and researchers involved in 'teaching' the same thing, In fact the researchers were not involved in teaching, but were involved in supporting the use of the technology. The need for this type of input would reduce once the HOMEWORK system moved from being a research prototype to a stable fully functional system. Parents certainly were more involved in teaching. This is a key benefit of the HOMEWORK system approach. Parents exist as a resource in the natural 'non-homework' condition. However, by considering parents and the home environment in the design of HOMEWORK and designing the system to work across home and school contexts it is probable that children were making better use of home resources such as parents. And that parents too were making better use of home resources, such as counting out pocket money, than they might otherwise have been.

So, whilst the HOMEWORK situation is perhaps less ideal than it might appear initially, the question of how the Ecology of Resources framework could be useful in more informal or fluid situations when the surrounding context is less clear and the curriculum less well specified still requires investigation. The next example starts to explore this question through the way that the Ecology of Resources model is being used in the VeSEL project.

The Ecology of Resources as a Design Framework: The VeSEL project

The overarching aim of the VESEL project (www.veselproject.net) is to enable rural communities in Sub-Saharan Africa, initially in Kenya, to use advanced digital technology to improve their agricultural practices and literacy levels. The VESEL team is multidisciplinary and includes radio communications, sensor network and power engineering expertise as well as software internationalization, socio-technical, participatory design and educational technology experts. The UK team is also collaborating with partners at the University of Nairobi with expertise in Agriculture and ICT. The design process being adopted for the development of the technologies to be employed is both iterative and interdisciplinary. The team completed the first phase of their work between October 2006 and March 2007. This first phase involved Context Mapping activity for two areas within Kenya: a group of farmers in Kiangwachi in the Mount Kenya area, and a group in Kambu, a small town in the south of Kenya, half way between Nairobi and Mombassa. The initial design brief for the VeSEL team was to specify a ‘resource kit’ to support the development of more effective farming practice in these two communities. At the time of writing this paper the project is in the middle of prototype design activity as part of Phase 2 of the iterative design process. In order to progress the design of the VESEL resource kit a series of ‘sketches’ and low-tech prototypes have been produced and evaluated with colleagues at University of Nairobi and within the two rural faming communities in Kiangwachi and Kambu. Our current activity is focused upon two scenarios, one for each community. The Ecology of Resources framework is useful at this stage of the design for mapping the potential resources that could be included, the links between them and the potential barriers. The purpose of including this example here at such an early stage in the project is to demonstrate the way in which the Ecology of Resources framework can be used as a design tool in very different circumstances to those faced by the Homework project team. An extract from the scenario for the Kambu community in Kenya is presented below, first as a narrative and secondly using the Ecology of Resources framework to model the context that the proposed scenario could create with the community in Kambu.

Growing Water Melons in Kambu 1

Kambu is a small town in the south of Kenya, half way between Nairobi and Mombassa. The area around Kambu is one of the poorest parts of Kenya as the area suffers from drought and has not yet been able to grow crops such as French Beans and Baby Corn as grown elsewhere in Kenya and exported to European supermarkets. The Kambu community is spread out over a wide area and the farms are remote from the main roads even though Mtito Andei, the nearby town centre is a stopping area on the main Nairobi to Mombassa road. The community is supported by the Mtito-Andei Development Initiative (MDI) named, like the town, after the Mtito-Andei river which forms a boundary between their community and the Tsavo East National Park. The MDI group had formed in 1997 to help the 29 local villages eradicate the Tsetse fly, which is a particular problem here, because it is carried by wild animals from the neighbouring National Park. The MDI group is still working together and has recently built a Seed Bank.

The design scenario being developed with the Kambu community and in particular in collaboration with the MDI group and Silanga primary school has the following aims:

1 - Improve knowledge of water resource management and water usage leading to improved agricultural practice, food security and income.
2 - Improve knowledge of appropriate crops, initially using Water Melons as an example
3 - Enable teachers and others to explore the use of ICT to improve basic skills

In order to address these aims the VeSEL team in partnership with the MDI group will help Silanga school to start an agricultural club (called a 4K club) and a demonstration shamba (a small agricultural plot) at a location near an existing water pump. A teacher at Silinga school who has a successful agricultural plot himself will be a key local partner here. The shamba will be 'technology enhanced' using the VeSEL resource kit and will be used to educate the community about effective water management and to illustrate good water management practice through the introduction of Water Melons as a new crop. The shamba may also provide some food.

Educational content relating to water management and good agricultural practice for arid lands will be provided on a local content server in Kambu at the radio station. This content is disseminated to the school where it is used to support the development of the demonstration shamba. Pupils and staff are involved in recording the Shamba demonstration project and communicating it using activities and technology from the VESEL technology resource kit. These activities result in multimedia (audio/video/text) presentations. The VESEL technology resource kit, which includes sensors for measuring local agricultural and weather conditions and provides remote access to a global agricultural database, is portable, so that it can be carried on a bicycle. The bicycle in turn can be used to charge some of the devices and enables the teacher who manages the kit to cycle between his home, the school and the shamba.

Dissemination to the community is through what people see or hear about happening at the school shamba and through radio broadcasts and public meetings. Reports on project progress are broadcast locally through Radio Mangelete. Staff and children at school are able to listen to broadcasts (and interactive radio) using wind up radios. These wind-up radios may also be used to charge low power items in the resource kit, such as mp3 players. MP3 players with integrated radio can be used to record interactive education broadcasts, which can be archived and played back using low powered FM transmitters and the wind-up radios.

Growing Water Melons in Kambu 2

At the outset of the discussion about the Ecology of Resources framework the following question was identified as an important driver: *how do we use technology to scaffold learning in a connected world where resources are no longer tied to the desktop?* This question is as apt in the Kambu scenario as it was in the more formal Homework situation. In Kambu we need to use technology effectively to link and marshall the most appropriate resources for the learners. The resources and landscape are a little different and more distributed, as too is the nature of the connections: the question however remains the same.

If we take the learners as the starting point for our Ecology, we can consider an individual member of the community, a child at the school, a family member, a farmer or the community as a whole. For the purposes of this example I have selected a child at Silanga school as our learner to provide a more direct comparison to the Homework project example.

The Skills or *Knowledge* that our learner needs to learn about are those that relate to water management with respect to growing water melons in arid conditions. There will also be ICT skills, but here, for the purposes of brevity we will focus on the agricultural knowledge. This agricultural knowledge is not part of a formal curriculum. However, the aim is to instill good practice and the information that will be provided by the VeSEL resources will be organised according to the guidance validated by our agricultural expert. There will also be accepted community beliefs about good farming methods, that will be organized according to tradition, as stories for example; such as that used by the MDI group to explain the purpose and use of the seed bank.

The *Resources* that might help our primary school learner learn about growing water melons include: people at her school and within her family, MDI and the wider community; the demonstration shamba that is enhanced by the technology from the VeSEL resource kit including sensors for measuring local agricultural and weather conditions, access to a global agricultural database, the water pump; the content server at the radio station, the bicycle, wind up radios and MP3 players. The administration of these resources is organised in a variety of ways, the teacher manages the resource kit and shamba, the radio station has a manager and there are customs and practices that influence access to the human resources.

The *Environment* in Kambu has many of the same features as that surrounding the Homework project sites, there is a school, houses, shops and farms. However, there are also stark differences that impact upon the nature of the technology that can be introduced. For example, there is little electricity and no existing internet access. The organisation of the landscape both within and outside the school is also importantly different, children in school do not all have desks and the distance they travel to school is often quite large. The selection of location for the demonstration shamba is near a local water pump to ensure water availability. This location is not at the school and will entail some traveling.

If we consider each of the elements in our Ecology factors that impact on the design process for our educational technologies can be identified. For example, if we consider the *Curriculum* filter that organizes the knowledge to be learnt it is clear that there is a potential tension at this point in our Ecology between what the community believes to be good farming practice and what current agricultural expertise believes to be good practice. As highlighted in the earlier discussions, the elements in any Ecology of Resources have a role in the wider cultural and political system. This wider context influences the manner in which we might tackle the tension identified as much as it is influential in the existence of the tension. If we consider the *Administration* filter between the resources and our learner the nature of the arrangements that will constrain our learner's access to the resources is influenced by the need for someone, in this case the teacher, to take responsibility for the resources that make up the VeSEL resource kit.

In addition to exploring the constituents that make up the elements in the Ecology of Resources, it is also useful to investigate the links between these elements. For example, the link between the knowledge to be learnt and the nature of the environment is very strong. The link between the resources, the knowledge and the environment is also strong. For example, the distances between different locations such as the teacher's home, the school and the shamba are quite large, a bicycle as a form of transport is appropriate. This bicycle can also carry and power some of the technology. In contrast, this would not have been an option in the environment that contributed to the context of the Homework project.

This very brief example extracted from the VeSEL design activity merely scratches the surface of our context model. The role of this example within this paper is to offer a contrast to the Homework example and to illustrate how the Ecology of Resources framework can be used to support design in a very different and less 'ideal' situation. The design process can be assisted through the identification of the elements that are present in an existing context. This in turn can help indicate where effective technology interventions might be made. If these potential technology interventions are then mapped onto the framework we can start to see how they might support the essential links between the elements. Exploring the context using the Ecology of Resources approach also helps to identify tensions within and between the elements. The use of participatory design methods helps us to identify some of the features of the wider context that can inform how we tackle these tensions and how we design the technology enhanced interventions. It is interesting to note that both the Homework and the VeSEL Ecologies have a primary school aged learner at their centre. One could equally focus on parents in both the Homework and the VeSEL examples, placing them at the centre of the Ecology and considering how learning at home and in school could be linked though technology: a tablet PC as part of the HOMEWORK system and perhaps a wind-up MP3 player as part of the VeSEL resource kit. The Ecology of Resources model helps us to identify the important differences and similarities between such contexts and what the implications of these are for our design activity.

The Ecology of Resources model: Educational Theory Development and Future Directions

Finally we turn our attention to consideration of the way in which exploring the Ecology of Resources model might progress discussions about educational theory and the learning-teaching process. We observed earlier that a learner's activity has little impact upon the nature of knowledge and curricula, likewise they often have little impact upon the organisation of their Environment. Hence in Figure 2, there were bi-directional arrows linking *Knowledge*, *Resources* and *Environment*, and linking *Curriculum*, *Administration* and *Organisation*. However, the arrows between a learner and her Environment and between a Learner and the Knowledge she seeks are uni-directional.

There is an ever-growing increase in the variety of technologies and in the availability and use of tools that enable people to digitally capture aspects of their environment, such as photos and

GPS data, and to easily create and publish their own materials; from web pages, wikis and blogs, to pictures and video clips. This extends the capacity to create learning contexts beyond teachers, academics, designers and policy makers. This makes the challenge for the future one of developing ways in which technology can support learners to effectively create their own learning contexts. What we might call a *Learner Generated Context* can be defined as a context created by people interacting together with a common, self-defined goal. For example, if we accept the view that a context can be described as a user centric Ecology of Resources then a Learner Generated Context is one in which a learner or group of learners marshall the resources available to them to create an ecology that meets their needs. An example of such a Learner Generated Context enabled through technology might be as follows:

Members of a community environmental centre use a variety of technologies to
- collect and publish data, for example about pollution gathered from a local sensor network;
- offer a resource bank of information, for example through a wiki so that anyone who is interested can contribute to the body of knowledge about the local environment, this includes pictures, text, links to other local resources including area maps, recycling points and conservation areas;
- allow people to discuss issues of importance.

These resources enable the group to attract the attention of local politicians so that they have a voice for environmental issues. They are also used as the basis for a course for all centre volunteers, thus validating the organisation of their contextually generated knowledge.

In some senses all contexts can be described in this way: all are created from some combination of human enterprise in the world. The key aspect of Learner Generated Contexts is that they are created through the enterprise of those who would previously have been consumers in a context created for them. However, in order to progress this agenda we need to increase our understanding of how to scaffold learners to effectively generate their own learning contexts.

The *Ecology of Resources* model of context, and the associated design framework being developed, aims to offer support for this more democratic learning economy. This activity will involve the development of new educational theories that can encompass situations where the balance between learner and teacher or mentor control is constantly changing. The type of learning relationship that we discussed at the outset when we considered the ZPD, ZAA and ZPA is one in which activity between a learner and a more able partner has been described as "learning by transaction" (Bruner, 1985). This captures something of the essence of the Russian term “obuchenie” that describes the teaching and learning process. The term itself is often translated as "instruction", which is inadequate. This reflects the lack of an appropriate term within the English Language to describe the learning and teaching process as one. We also lack the correct terminology to describe the particular nature of the relationship between teachers and learners that technology is precipitating. We now face a situation in which the teachers and experts, who know more than the learners about the ‘stuff’ we want people to learn, may well not know as much as the learners about the technologies that could act as learning tools. There is now a real opportunity for reciprocal teaching and learning. Learners need to know how they can use these tools to learn more about a particular subject or skill, and teachers and experts need to know enough about these tools to scaffold learning. It should be a collaborative relationship where the more able partner is both the teacher and the learner, but with respect to different expertise. This observation suggests the need to explore the extent to which we understand enough about this relationship to reap its advantages for learning and to scaffold the creation of effective learner generated contexts. Some early work in this direction is that discussed in Underwood, Smith, Luckin & Fitzpatrick (in press) a paper also in this special issue. This paper considers how we might reconfigure the teaching and learning process, enable learners and scientists to communicate around mutually beneficial collaboration and so “enable educational e-Science communities to grow and build the contexts within which they can efficiently share and exploit resources” (ibid).

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