Learning Contexts as Ecologies of Resources: A Unifying Approach to the Interdisciplinary Development of Technology Rich Learning Activities

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Abstract - This paper addresses the problem of how to develop a conceptualization of context that can support the development of technology-rich learning activities. The term *technology-rich* encompasses mobile, hybrid and on-line learning approaches and the work reported here is intended to bridge these different approaches. In this paper we suggest that a learner-specific definition of context can ground research across mobile, hybrid and on-line learning. We discuss a definition of context that is theoretically grounded in the socio-cultural approach to learning and that has been used to develop the Ecology of Resources model. This model is an abstraction that can be shared between social and technical researchers and practitioners to support analysis and to generate technology design. An example that demonstrates the way that the Ecology of Resources model is empirically as well as theoretically grounded is presented. This example is used to support the proposal that the Ecology of Resources model can be used as a design tool to sensitize designers to the importance of each learner's context.

Keywords - context, zone of collaboration, ecology of resources model, distributed scaffolding.

I. INTRODUCTION

The continuing increase in the range of pervasive, interconnected, and embedded technologies in our environment allows people to digitally link their experiences across, between and with multiple locations, multiple people and a range of subject matter. These technical developments have the potential to support the better integration of learners with their social, physical and digital worlds. Or in other words these developments have the potential to enable us to take batter account of each learner's context. The aim of this paper is to discuss the concept of context and to evaluate a context-based model of learning that is intended to support the development of technology-rich learning activities. The model is called the Ecology of Resources and it offers a potentially unifying concept for the sub-fields of learning with technology, both technical and sociological. In particular, the Ecology of Resources model aims to engender the development of activities that use technology to overcome the traditional physical and temporal constraints that are part of many learning environments and that are at the heart of approaches within the sub-fields of mobile, hybrid and on-line learning.

In this paper we extend [1] and discuss the Ecology of Resources model to consider some of its theoretical grounding. We then present an empirical example of the model in use. This example is drawn from the Homework research project: a project that explored the use of multiple technologies to support young learners (aged 5-7 years) with numeracy both inside and outside school. Such a situation is particularly compatible with the aim of the Ecology of Resources to support the development of activities that use technology to overcome the traditional physical and temporal constraints. This type of empirical evaluation adds both to our understanding of learners' interactions with technology, and to the continuing development of the Ecology of Resources model and design approach.

II. CONTEXT AND LEARNING

There is nothing new about the suggestion that one should explore the educational context in which learning takes place in order to understand more about learning. Work such as that completed by [2] suggests that the organization of learning resources, including the computer, influences the manner in which these resources are used. Similarly [3], when evaluating Integrated Learning Systems, concluded that the impact of technology upon learning was heavily dependent on the specifics of the educational environment into which the technology was introduced. This type of work is useful in confirming the importance of looking at the wider environment, but is limited by a focus that is mainly on specific environmental locations, such as school classrooms. To make the most of the possibilities afforded by new technologies *a clearer, learning-specific definition of context* is now required, to support the development of technology-rich learning activities. Activities that take advantage of the growing range of

technological artefacts that can support interaction across multiple physical and virtual spaces, multiple knowledge domains, multiple time periods and with multiple collaborators. The provision of such a definition is not an easy task. Nardi, [4] states the problem clearly: 'How can we confront the blooming, buzzing confusion that is "context" and still produce generalizable research results?'

In [5], we confront this "confusion" by looking at a range of ways in which context is talked about within literature drawn from multiple disciplines to identify common themes of concern that transcend disciplinary boundaries. This encompasses work drawn from geography and architecture, anthropology and psychology and from education and computer science. We conclude that:

> "Context matters to learning; it is complex and local to a learner. It defines a person's subjective and objective experience of the world in a spatially and historically contingent manner. Context is dynamic and associated with connections between people, things, locations and events in a narrative that is driven by people's intentionality and motivations. Technology can help to make these connections in an operational sense. People can help to make these connections have meaning for a learner.
>
> A learner is not exposed to multiple contexts, but rather has a single context that is their lived experience of the world; a 'phenomenological gestalt' [6] that reflects their interactions with multiple people, artefacts and environments. The partial descriptions of the world that are offered to a learner through these resources act as the hooks for interactions in which action and meaning are built. In this sense, meaning is distributed amongst these resources. However, it is the manner in which the learner at the centre of their context internalizes their interactions that is the core activity of importance. These interactions are not predictable but are created by the people who interact, each of whom will have intentions about how these interactions should be. " [5]

This definition portrays context as something that is centred around an individual. This results in a conceptualization of context with a time-scale that is an individual's life and boundaries that are those of the individual's interactions. We suggest that this definition of context can be used to ground the development of technology rich learning activities that do not differentiate between the various flavours of learning that inhabit the growing rhetoric of descriptors that include mobile, hybrid, virtual, on-line, and e-learning. All are concerned with learning and all can be supported by such a learner centric definition of context. But what theory of learning is consistent with this view of context and capable of being used to develop a context-based model of learning that can be made operational and that can form the foundation for a design framework?

There are several theoretical viewpoints that specifically relate to learning and context; for instance, work from the socio-cultural tradition, such as that of Vygotsky, activity theory, Michael Cole's cultural psychology, Hutchins' distributed cognition and the situated and communities of practice approaches. The discussion of context above favours an intentional role for people, a learner-centredness that defines context as an interactional concept, combining a learner's active experience of their physical reality with their mediated experiences through human-made artefacts.

The process of internalization through which an individual's distributed meaning-making interactions lead that individual's development is key to this enterprise. This narrows down the compatibility of the potential learning theories to those from a socio-cultural stance. The relational attributes of activity systems certainly make them appealing for this purpose. However, it is my intention to focus upon the learner at the centre of their interactions we therefore consider in more depth the socio-cultural approach of Vygotsky [7] [8]

A. Vygotsky, Learning and Context

The socio-cultural approach of Vygotsky is developmental and describes an individual's mental development as an interaction between that individual and their socio-cultural environment. The nature of these interactions influences the nature of their resultant mental processes; the interpsychological becomes intrapsychological via the process of internalization [7].

This approach offers compatibility with a context-based model of learning and is further focused in the Zone of Proximal Development (ZPD), which can be described as the crystallization of the internalization process. When Vygotsky [7] introduced the ZPD, he proposed that a child's ability to solve standardized problems unassisted was not the whole story of their development, but rather it simply reflected the completed part of their development. The ZPD was defined as:

> "The discrepancy between a child's actual mental age and the level he reaches in solving problems with assistance indicates the zone of his proximal Development; … Experience has shown that the child with the larger zone of proximal development will do much better in school. " [7]

Vygotsky suggested that when instruction is aimed at what the child can achieve when aided by a more able partner then it can play a major role in the development of that child's higher mental processes. The purpose of the ZPD is to focus the dialogue between the more able partner and the child, so that the learner can reflect upon this dialogue and reformulate it into their own thought [10].

The ZPD has an important *process* element as well as a conceptual one. This process element can be seen more clearly in Vygotsky [8], in which the ZPD is described as something that must be created through instructional interactions and that can only operate when the child is interacting with other people in the environment.

The ZPD could be thought of as the basis for a context of productive interactivity. However, the ZPD is underspecified; it does not, for example, specify the manner in which the 'actual developmental level and the zone of proximal development' [8] are to be identified. This need for clarification has been recognized by many researchers, such as [11 and 12]. Work such as the scaffolding metaphor of [13] and the constructs proposed by [14] have provided useful clarifications about how a ZPD might be created and have informed the interpretation of the ZPD that this paper discusses and that is at the heart of the Ecology of Resources.

My interpretation explores the relationship between the identification of a learner's collaborative capability and the specification of the assistance that needs to be offered to the learner in order for them to succeed at a particular task. We refer to this interpretation as the Zone of Collaboration, which uses two additional constructs called:

The Zone of Available Assistance (ZAA);
and
The Zone of Proximal Adjustment (ZPA).

The ZAA describes the variety of resources within a learner's world that could provide different qualities and quantities of assistance and that may be available to the learner at a particular point in time. The ZPA represents a sub-set of the resources from the ZAA that are appropriate for a learner's needs. Figure 1 represents these concepts graphically.

B. Scaffolding

As can be seen from the discussion so far, the ZPD requires assistance for the learner from a more able other. The nature of this assistance was, however, left underspecified in Vygotsky's writing. Seminal work done by David Wood [9], in which he coined the term 'Scaffolding' to describe tutorial assistance, is particularly relevant here. Effective scaffolding is presented as something more than the provision of hints and graded help. It involves simplification of the learner's role and interactions in which learners and their more able partners work together to achieve success, but the contributions from each vary according to the child's level of ability [15].

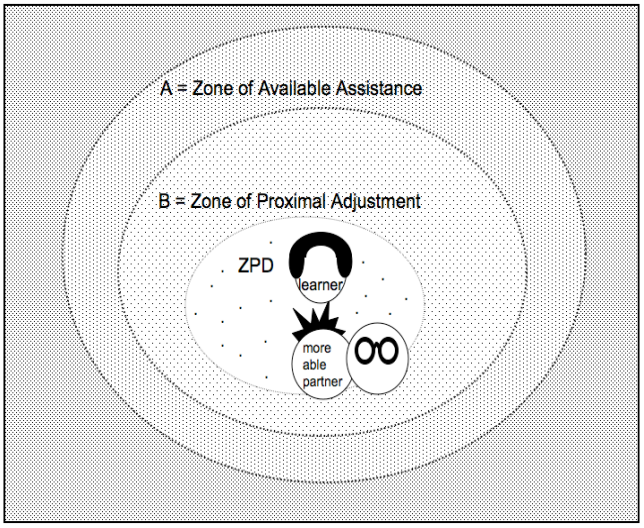

Figure 1 The Zone of Collaboration [5]

The scaffolding approach has been used to develop a variety of educational software, such as that of Wood, Shadbolt, Reichgelt, Wood & Paskiewitz [16], and has been used, adapted and extended to guide the development of a variety of technology enhanced learning applications (see for example, [17, 18, 19]). A further dimension to the use of technology for scaffolding can be seen in the use of scaffolding to support the development of higher order thinking skills, such as metacognition [20] and help-seeking skill development [21].

The potential offered by connected technology and the need to focus on context as discussed in the introduction to this paper require that consideration is given to resources that are beyond those offered by a single interactive learning environment, which is where most of the research attention has been focused to date. Some consideration has however started to be given to the possibilities afforded by scaffolding in these much more complex environments. [22], for example, use the term 'distributed scaffolding' and explore this through classroom-based science learning. Key findings from their work include identification of the increased complexity that occurs when scaffolding is distributed and the potential for distributed scaffolding to offer learners more opportunities to notice scaffolding opportunities. Tabak [23] also explores complex settings and distributed scaffolding and also identifies this positive possibility of increased opportunities for scaffolding. Her vision for distributed scaffolding is that learners can take advantage of different types of support provided by different means in an integrated manner, in order to solve complex problems. This notion of distributed scaffolding is increasingly important when a learner's broader context beyond a single learning environment is considered.

We therefore add to the definition of context that:

> "it is the role of the more able participants to scaffold a learner's construction of a narrative that makes sense of the meanings distributed amongst the resources with which they interact. Through this scaffolding the learner at the centre of their context internalizes their interactions and develops increased independent capability and self-awareness."
>
> [5]

III. THE ECOLOGY OF RESOURCES MODEL OF CONTEXT

The Ecology of Resources model builds upon this definition and develops the ZAA and ZPA concepts into a characterization of a learner and the interactions that form that learner's context. An earlier version of the model is discussed in [24] and its full detail can be found in [5]. Here we describe it briefly in order to ground the presentation of an empirical example and to support the suggestion that it might act as a useful mediating artefact to integrate work across various subfields such as mobile and hybrid learning (see Figure 2 for an illustration of the Ecology of Resources model).

The resources that comprise a learner's ZAA embrace a wide range of types, including people, technologies, buildings, books and knowledge. It is useful to consider the different types or categories of resource that might be available in order to help us identify them and the relationship they bear to the learner and to each other. One of the resource categories that the learner needs to interact with comprises the 'stuff that is to be learnt': the knowledge and skills that are the subject of their learning. A second category of resource is that described as 'Tools and People'. This category includes books, pens and paper, technology and other people who know more about the knowledge or skill to be learnt than the learner does. The last category of resource is that represented by the 'Environment' descriptor. This category includes the location and surrounding environment with which the learner interacts: for example, a school classroom, a park, or a place of work. In many instances, there is an existing relationship between the resources within these three categories: Knowledge and Skills, Tools and People and Environment. For example, the book resources appropriate for learning French are located in the Language Learning section of the library and formal lessons probably take place in a particular location in school. Hence, in Figure 2 the categories of resource surrounding the learner, and with which they interact, are joined together. In order to support learning, the relationships between the different types of resource with which the learner interacts need to be identified and understood. They may need to be made explicit to the learner in order to build coherence into the learning interactions. For example, if we wish to teach French conversation to an evening class, which involves how to order a meal, we may choose to provide a menu and to organize the room like a restaurant. We will also need to ensure that the language concepts we introduce are relevant to meal ordering.

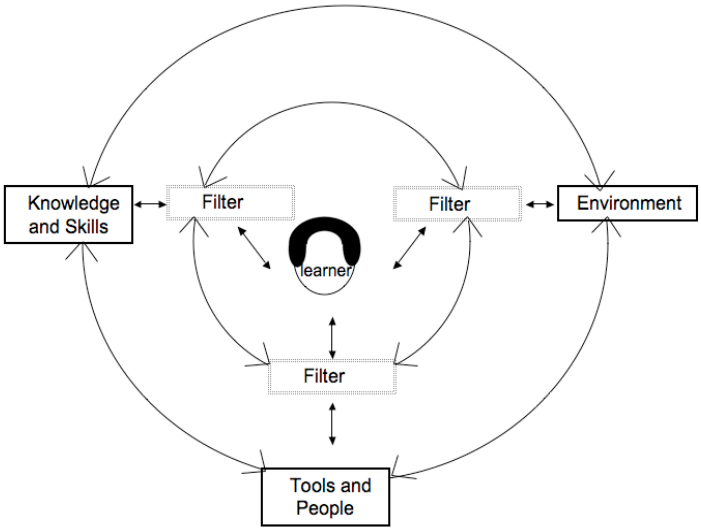

Figure 2 The Ecology of Resources Model [5]

A. *The Ecology of Resources Filter Elements*

This language-learning example highlights another factor that needs to be taken into consideration. We mentioned that we might organize the room in a particular fashion. This is an example of the way in which a learner's interactions with the available resources are often filtered by the actions of others — in this case, me as the teacher — rather than experienced directly and unimpeded by the learner. For example, the subject matter to be learnt is usually filtered through some kind of organization, such as a curriculum, that has been the subject of a process of validation by other members of the learner's society. This resource filter is stronger for subjects such as mathematics and other formal educational disciplines than for more grounded skills such as farming. However, even with skills-based subjects there is, to some extent at least, still some formalization of what is recognised as the accepted view about the nature and components of the skills that need to be mastered. The tools and people that may be available to the learner are also organized or filtered in some way. For example, a teacher taking a French conversation evening class is only available during that class, or perhaps at some other times via email. Classroom technologies are not always available to learners whenever they want: there are school rules and protocols that restrict the learner's access to resources. Finally, and again as reflected in the French conversation learning example, a learner's access to the Environment is mediated by that Environment's Organization. This resource filter 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. In the same way that there may already exist a relationship between the different

resource elements in the outer circle of Figure 2, there may also exist a relationship between the filter elements. The coherence of the learner's experience can be enhanced through careful consideration of the existing relationships between the filter elements and between the individual resource elements and their associated filter. All of the elements in any Ecology of Resources bring with them a history that defines them, as well as 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.

IV. THE ECOLOGY OF RESOURCES MODEL IN USE

The Ecology of Resources model offers a way to talk about learners holistically – to sensitize us to the range of interactions that constitute their contexts, to frame the participatory design process; to explore data to understand more about learners' contexts; to identify the assistance that could be available and the way that learners' interactions with it might be filtered and supported and to identify situations where scaffolding might be used. The Ecology of resources approach has been used in a variety of projects that include science learning in school, informal and formal learning in the developing world and home education in the UK.

The example we draw upon here is that of the Homework project through which a system called HOMEWORK was developed. This was an interactive mathematics education system for children aged 5–7 years. The system used a combination of interactive whiteboard and Tablet PC technology, plus some bespoke software, consisting of lesson planning, control and home use components. The system contained a rich set of multimedia and associated interactive numeracy resources drawn from the popular television series called the Number Crew. Teachers used the software to link resources into lesson plans. In the classroom, the interactive whiteboard was used for whole class activities and each child also had their own Tablet PC for individual and small group activities. The teacher could control the classroom activity from their own Tablet PC and could allocate new activities or send messages to individuals or groups of children in real time. When planning each lesson the teacher could also decide upon homework activities and allocate them to individual children's Tablets as appropriate. After school, the children took their Tablet PC home with them and used it at home or elsewhere; individually or with parents. At home, in addition to homework activity set by the teacher, the Tablet provided access to the resources the learner had used in class that day, the resources that they had used 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 related. There were also links to other relevant fun activities and a messaging system to support parent and teacher communication. The HOMEWORK system was developed incrementally and interactively with learners, teachers and parents. Each iteration gave the design team a clearer understanding of the interactions that made up the learning contexts of the children who the system was developed to support. It is described in some detail in [24]. Here, we use the example of the system that was the product of this development and its empirical evaluation to demonstrate its use of mobile, classroom and e-learning technologies and the manner in which the Ecology of Resources model of context can be used to model learner interactions and design technology use.

Evaluations of the HOMEWORK system were conducted in different schools and classes throughout the system's development. The evaluation on which we draw in this paper was conducted with a class of 32 children aged 5–7 years. The research was exploratory and was concerned with understanding the nature of the learning interactions that learners, teachers and parents were able to engage in supported by the HOMEWORK system. There was no intention to set up a comparative control group trial.

Multiple data sources were collected which included: logs maintained by the system; diaries maintained by parents; interviews with parents; and questionnaires completed by parents. In this example we focus upon the data that illustrate how the Tablets were used by children and their families outside the classroom. It is these data that can offer valuable information about the child's wider learning experience across multiple locations, tools and with a variety of other people.

The HOMEWORK system was used for three, hour-long mathematics lessons per week in school. The log data indicate that the Tablets were used at home, on average, slightly less than once a day for the equivalent of 25 minutes a day. However, there was great variability in both session length and in the total time children spent using the Tablets during the research period. The diaries maintained by parents indicate that the most common time for the Tablet to be used was weekday evenings (after 5.30 pm) and during the daytime at weekends. These diaries also reveal that the Tablet was most often used at a table located in a communal space such as a lounge, and that mum was the person who most frequently helped children with their Tablet activities.

There was also evidence of learning gains during the time the HOMEWORK system was in use. These can be seen in the changes in children's scores in a pre-test and post-test set by the teacher. The mean scores for the youngest children (5–6 years of age) increased by 17 per cent between the start of the study (T1) and the end of the study (T2); and for the older children (6–7 years of age) by 26 per cent, as illustrated in Figure 3.

In addition to these test scores, parents' comments in the diaries they maintained and during interviews also suggest that children's learning may have benefited during the

Homework project studies. For example, a parent commented about her daughter Jane:

> "Jane wanted to go through the videos of the number crew. Jane has definitely found having the PC a more interesting way of doing maths, as with most things, seeing and having an active part to play means more than just listening. Jane said that she had learnt a lot this weekend and showed me ½s and = and 10s and 100s counting on and backwards and you could tell how pleased she was with herself. Jane cleaned the PC and is taking great care of it."

In the interviews with the class teacher there are also reports that reflect the teacher's belief that children are benefiting from their use of the HOMEWORK system. The findings from the interviews, both with parents and teachers, provide confirmation of the pre-test/post-test data.

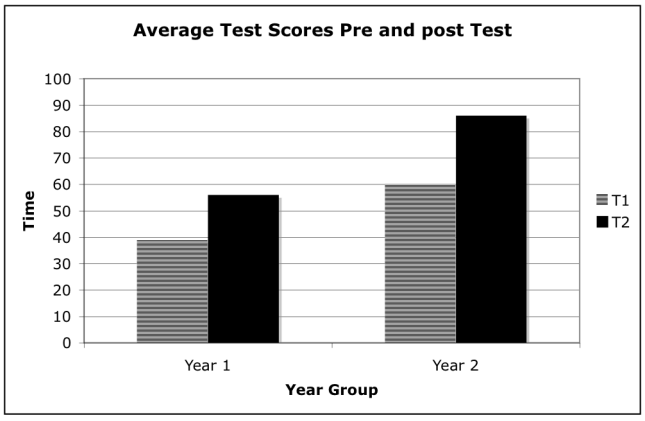

Figure 3 Average test scores pre and post system use

A. Family Case Study

In addition to this data about learning gains and how, when and where the tablets where used, the project team also wanted to explore more about the nature of the way in which the system may have supported learning, and the range of interactions that the HOMEWORK system was able to support. The multiple data sources were therefore pulled together to produce narrative family case studies. We discuss an excerpt from one such case study here to illustrate one family's use of the system in more depth. This narrative is about a learner — Robert, and his family — and the way that they used the HOMEWORK system through the Homework Tablet. The narrative is constructed from the data logged by the Homework Tablets and the entries made in the diary kept by the family. The timings for the length spent on activities are rounded down to the nearest minute. The '…' symbol indicates where there is a day's entry in the full narrative that is not part of this extract.

1) Robert's Story (an excerpt)

Robert is 5 years old and lives at home with his parents and two brothers.

It's Wednesday and Robert has used his Tablet PC in school this morning, from 11.20am, working on an activity about estimating a number of objects. He watched a video to begin with and then worked through activity number 7. He completed activity number 7 at level 1 for 5 minutes, skill number 7 at level 1 for 3 minutes, activity number 7 at level 2 for 2 minutes, skill number 7 at level 2 for 3 minutes and activity number 7 at level 3 for a little over 2 minutes. He finished at 11.45am.

Robert takes his computer home this evening and uses it at 6.10pm. He works in the lounge, sitting on the floor with his Tablet PC on the coffee table, with his grandmother and brother. He works on the 'Number Themes' digital camera homework for about 15 minutes (6.10pm – 6.25pm). This asked him to look for numbers in his home and to take photographs using the camera integrated into the Tablet PC. He takes 2 photos, which do not come out very well. Mum says there was not enough light to take photos (in diary). He then has a look at the other homework activity called 'Number Bags' at about 6.35pm.

…

Friday - Robert's teacher uses the HOMEWORK system for the maths lesson today and starts the session with the whole class together sitting on the floor in front of the interactive whiteboard singing the Number Crew song, watching a video and completing a numeracy activity. Each child then returns to their seat and uses their individual Tablet PC. Robert uses his Tablet PC this morning at 11.45am for about 20 minutes. The teacher has set some homework and Robert looks at this while the teacher explains it to the class. The homework activities for this week are called 'Numbers are everywhere', which involves using the Tablet PC camera to take pictures out of school of numbers up to 100 around the house and then complete a worksheet; an interactive activity called 'Ten Down'; and a video called 'Storm and Seasickness 1'. Robert has a practice with the camera, for about 10 minutes, and takes and looks at some pictures.

Robert takes his Tablet PC home for the weekend today. He uses it when he arrives home from school at 3.45pm. He works at the kitchen table with his brother. He looks at the fun activities and the homework. He then spends 25 minutes doing the 'Ten Down' homework activity (see Figure 4), from about 3.50pm – 4.15pm and briefly looks at the 'Numbers are everywhere' camera homework sheet. He turns on his PC again at 5.20pm and once again

works at the kitchen table, this time with Mum. He looks at the 'Numbers are everywhere' homework again, has a 2-minute go with the camera, during which he records a video and then has another little play with the 'Ten Down' activity for 10 minutes. This involves a lot of exploration as Robert looks at a number of different activities for a few minutes each. He keeps coming back to the Tablet PC: he plays for about 20 minutes at 5.35pm, then 10 minutes at 6.10pm, then again for about 10 minutes at 6.50pm. Mum says he really enjoyed the 'Ten Down' activity and grasped it quickly. The day's session finally ends at 7pm.

Saturday Robert uses his PC again on Saturday morning, turning it on briefly at 8.40am when he returns to the 'Ten Down' exercise for 5 minutes, working in the lounge. At 10.30 am he works at the kitchen table with his Nanny and wants to repeat the 'Ten Down' activity as he had enjoyed it. He also explores a little more and looks at the fun activities and the activities that he did at school yesterday. He has another look at the 'Numbers are everywhere' worksheet, and takes a picture with the Tablet PC camera.

Figure 4 Ten Down activity

Robert's story offers an unusual and valuable insight into technology use out of school. It illustrates that he made use of the flexibility offered by the technology and used his Homework Tablet in a variety of locations, and at different times throughout the day. He could choose when and where to work on his numeracy within the constraints negotiated with his family. Sometimes he worked on an activity for a minute or two and on other occasions for longer. Robert worked on the homework activities set by the teacher, but did more besides and was able to choose what he wanted to work on, could show it to his other family members and, in so doing, behaved independently. He used the Tablet PC review activities completed in the past, both at school and at home: these activities might be whole class, small group or individually based and might use the fixed whiteboard technology or the mobile Tablet PC technology.

The nature of the technology is not the differentiating factor of Robert's learning experience. The homework system, with its combination of technologies, linked each learner's experiences at school with their experiences outside school, and helped provide conceptual coherence, so that the knowledge learnt at school was made relevant for home, too, and not seen as something that was only for formal school education. The empirical analysis also highlighted the fact that the experience that a learner has, when using a particular piece of content, is part of its personalization for that learner. So whilst two learners may both watch the same video clip or complete the same worksheet in their homes, their experience of this will be different owing to the interactions that surround their experience, such as the conversations they have with their sibling about the video clip or the comment that Mum makes whilst they are completing the worksheet. There can be no assumptions made about content that works well in school working equally well, or in the same way, when this same content is used outside school. The content needs to be adapted if the learning interactions we want learners to engage in are to be integrated both inside and outside school.

One of the important possibilities afforded by new technology is that it can also link together the people who are acting as MAPs in the different locations that comprise a learner's context. In the Homework project example this would mean linking parents and family members with the teacher and assistant, for instance. In fact this was achieved through various mechanisms: for example, there was a messaging service available with the tablet PC through which staff and parents could communicate; those at home could view the material seen by the child at school and look at the activities that they had completed, and vice versa for the teacher, who could view what the child had done at home. To make the most of this potential to link MAPs together across locations it is also necessary to increase our understanding of these MAPs and how learners engage them in their learning.

For example, at the end of the study, Robert's mother reported that he very much enjoyed his numeracy work. She also reported that the amount that Robert talked about numeracy had increased from that before he had the Tablet PC and that his requests for help and her provision of assistance had also increased.

All parents whose children took part in the study were asked to complete a numeracy attitude questionnaire at the beginning of the study. Those that returned a completed questionnaire (n= 29) were sent a second, identical post-study questionnaire. Nineteen parents also completed both questionnaires and their post-study answers were compared

against their pre-study answers. Each question was asked against a 5 point Likert scale ranging from 'Not at all' to 'Very much / All the time'. One of the questions parents were asked was concerned with their child's requests for help. This is an important element of the learner' interactions with their more able partners, such as parents and other family members. These interactions are key to the Zone of Collaboration and to the Ecology of Resources model of context. This question was:

Q6. My child asks for help with their numeracy homework

The average parental answer to Q6 about help changed from pre to post study more than any other question and in a positive direction, indicating that children were asking for more help when doing their numeracy work with the HOMEWORK system than they had done previously. Parents also reported that children were choosing to work on their numeracy more without parents asking them, and in preference to other subjects. They reported that their children's interest had increased and that their children enjoyed their numeracy work.

One of the major aims of the HOMEWORK system development process was to build a model of the learner's interactions that could take into account their interactions across multiple locations and with multiple other people. In particular, the technology was developed to help link each learner's experiences at school with their experiences outside school, and to help provide conceptual coherence, so that the knowledge learnt at school was made relevant for home, too, and not seen as something that was only for formal school education. The system also extended the application of the scaffolding concept beyond the learner to explore the possibility of scaffolding parental interactions with their children, and to help family engagement and communication with the school.

The HOMEWORK system interface on the Tablet PC mapped out some of the resources that could be accessed through the Tablet PC by a learner and those helping that learner. Figure 5 illustrates this and shows that the resources available are categorized as those that arise from the child's interactions when at school, those that represent the history of that child's interactions inside and outside school, activities that are part of the Homework set by the teacher and fun activities. There is also a messaging facility for communications with the teacher. These represent the ZAA resources offered by the HOMEWORK system software through the Tablet PC. Interactions between the learner and other resources, such as the learner's family, and features of their environment can also be supported through the Tablet PC, as illustrated in the description of Robert's interactions.

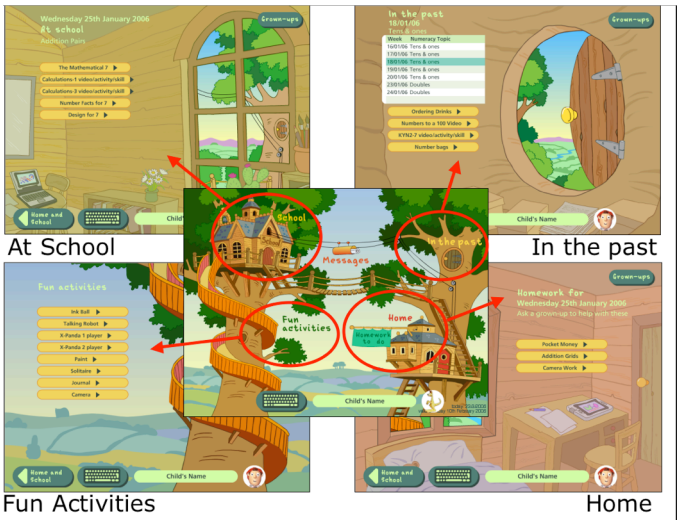

Figure 5 The HOMEWORK system interface when the tablet is out of range of the classroom network

As we stressed in earlier discussions about the role of the More Able Partner, the process of selecting resources to enable the construction of a ZPA is a negotiation between learners and More Able Partners. In a situation such as that described by the Homework case study, it is clear that in the out-of-school environment there may be various people who play the role of the More Able Partner at different points during the learner's interactions. Likewise, in the school environment, there will be the teacher, classroom assistant, peers, other teachers and parent helpers, each of whom may also fulfill the role of the More Able Partner at different points in time. The HOMEWORK system was designed to support both the child's learning and to support those in the position of the child's More Able Partner. It also had a part to play in the negotiation of the learner's ZPA with, and between, those playing the role of the child's More Able Partner, through, for example, the provision of information for parents and teachers about what each had done with the learner at home and at school. The ability to replay and review completed activities also offers each person acting as the learner's More Able Partner the ability to see what the child has done when either working alone or with another.

This emphasis upon the interactions between the different resources that a learner encounters is at the heart of the Ecology of Resources model that was used in the analysis of the data. Figure 6 illustrates the Ecology of Resources model for an extract of Robert's experience with the HOMEWORK system.

V. CONCLUSION

The Homework project has been used in this article as an example case study to demonstrate the empirical grounding of the Ecology of Resources model. The data from the project was also used to develop guidelines for the use of technology to support parental engagement. In

particular, the data and findings was combined with findings from another large study in the UK and reported in [25]. These includes, for example, highlighting the need for:

"- Carefully designed, parent focused support.
- Understanding what parents really need in order to help them get involved.
- Ensuring that continuity between in school and outside school is built, e.g. through carefully designed activities that aim to make work done at school relevant to the home context."

[25]

The findings presented in this paper draw upon fresh data examples and extend the discussions previously published in [26].

The definition of context that is discussed in this paper recognizes the interconnectedness of all the elements with which learners interact and the way in which these interactions shape our understanding of the world. Context should be considered as something that is defined with respect to an individual person:

> "it spans their life. A person's context is made up of the billions of interactions that they have with the resources of the world: other people, artefacts and their environment. These resources provide 'partial descriptions of the world' with which the learner can build connections through their interactions. These interactions help the learner to build an understanding of the world that is distributed across both resources and interactions: a distributed understanding that is crystallized with respect to a particular individual through a process of internalization."
>
> [5]

The Ecology of Resources model is offered as an abstraction that represents part of this reality for a learner, an abstraction that can be shared between social and technical researchers and practitioners to support analysis and to generate system design. It is concerned with learning and considers the resources with which an individual interacts as potential forms of assistance that can help that individual to learn. These forms of assistance are categorized as being to do with Knowledge and Skills, Tools and People and the Environment. These categories are not fixed, but rather offer a useful way of thinking about the resources with which a learner may interact and the potential assistance that these resources may offer. This emphasis upon the potential assistance that resources might offer highlights that it is the role that a particular resource element plays that is important, rather than its particularity. This emphasis upon context and the roles played by resources elements, including technologies, and upon the interactions between these resource elements means that the Ecology of Resources model could act as an integrative approach for Mobile Hybrid and On-line Learning. In this way the focus of the design process highlights the manner in which the resources and the relationships between them can be scaffolded and adjusted in order to meet the needs of the learner and to form their Zone of Available Assistance (ZAA).

The Ecology of Resources model is the basis for a design framework that offers a structured process through which educators and technologists can develop technologies and technology-rich learning activities that take a learner's wider context into account. This offers a basis upon which Distributed Scaffolding can be built. The process is participatory and iterative (for full detail see [5]).

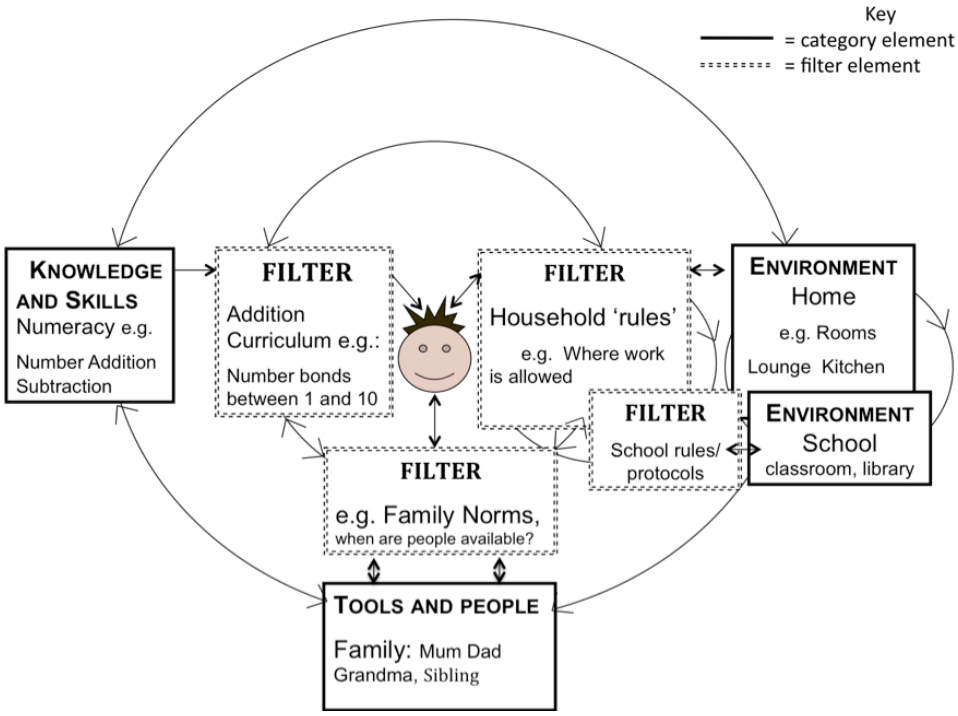

Figure 6 An example of an Ecology of Resources model of Robert's interactions with the HOMEWORK system.

VI.

VII. ACKNOWLEDGEMENT

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