Activity theory for designing mobile learning

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Abstract: Mobile computing offers potential opportunities for students’ learning. It is important to have an operational understanding of the context in developing a user interface that is both useful and flexible. The author believes that the complexity of the relationships involved can be analysed using activity theory. Activity theory, as a social and cultural psychological theory, can be used to design a mobile learning environment. This paper presents the use of activity theory as a framework for describing the components of an activity system for the design of a context-aware mobile learning application.

Keywords: activity theory; collaborative learning; context-aware learning environment; contradictions; design for context; mobile learning; usable.


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1 Introduction

Mobile telephone ownership and usage is now almost ubiquitous among student communities. More and more people are mobile-literate. Almost all young people today possess mobile phones. The increasingly powerful networks and handsets are making mobile learning a potential reality. The main advantages of using mobile computers for learning are that they assist students’ motivation, encourage a sense of responsibility, help organisational skills, help both independent and collaborative learning, act as reference tools, help track students’ progress and assessment (Savill-Smith and Kent,
Ubiquitous computing is much talked about today. It is the situation where technology becomes virtually invisible in our lives. Handheld technologies provide access to computing where student activities and learning occur, unlike desktop computers that are often segregated from other learning activities in the classroom.

Mobile technologies offer new opportunities for students’ educational activities in that they can be used across different locations and times. From a pedagogical perspective, there are many benefits to be gained by making the learning process interactive and collaborative. Mobile technologies offer us the flexibility of fitting learning into work process as a means of ensuring learning in practice (working). Learners have to continually strive to become an integral part of the community. Mobile technology also opens up the potential for children’s group collaboration (Danesh et al., 2001).

Group work with students and the research on psychology in education has demonstrated clear benefits of collaborative learning for young children (Rogoff, 1990; Topping, 1992; Wood and O’Malley, 1996). However, collaborative learning occurs only if the technology is designed to fit with the context of use for which it is intended.

The use of mobile technology is growing (Mandryk et al., 2001). Despite the rapid growth of mobile technology use by children, there is still little understanding of the ways mobile technologies can be designed to best support mobile collaborative learning. Mobile technology opens up potentials for students to work collaboratively rather than working with allocated partners at a desktop. Students can move around and interact with other students in different environments. Although there are potentials of mobile technology for students’ learning, a key restriction aspect of current handheld devices is the limited size of the screen. The design of usable mobile applications is not trivial. The environmental constraints of mobile devices, such as limited processing power and memory, affect not only the functional aspects of these devices but also the user interface. Mobile applications must be carefully designed to account for the limitations of their size, lower processing power and low bandwidth. Designing of successful mobile interfaces requires that context be taken into account. Mobile devices are especially well suited to context-aware applications because they are available in different contexts so that it is possible for us to draw on those contexts to enhance the learning activity (Naismith et al., 2005). It is generally accepted that a key feature of mobile devices and technology is context-awareness, whereby context and functionality are adapted to the user’s situation. However, the design of context-aware mobile devices provides us with major challenges in terms of both defining use context as well as developing appropriate concepts relevant to the design of contextual information on mobile interfaces.

Context plays a crucial role in the understanding and development of mobile learning applications. This means that user actions cannot be isolated from the environment in which they take place, that is, actions cannot be understood without a context. The user is an actor within an environment and the actor possesses certain ‘throwness’ in a situation (Winograd and Flores, 1986). Mobile devices and applications are susceptible to the contextual change and the user interaction with that context. It is the author’s belief that the complexity of the relationships involved can be analysed using activity theory. The structure of this paper is as follows. The implications of context for mobile design are discussed in Section 2. This is followed by a brief review of activity theory and its benefits in Section 3. The subsequent Section 4 describes how the principles of activity theory can be used to show the various components of the model for a mobile learning environment. The paper concludes with suggestions for further work in Section 5.
2 Context and its implications for mobile design

According to Preece et al. (1994), context is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them. Dey, Abowd and Wood (1999) define context as any information that can be used to characterise the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and application themselves. If a piece of information can be used to characterise the situation of a participant in an interaction, then its information is context.

Traditional computer applications have to consider only a fairly limited set of contextual concerns. These might include user characteristics (i.e. education and skills), working environment, system goals and organisational culture. Users performing tasks on these computers are stationary. Context concerns could be concretely taken into account during the design process and changed greatly after system completion. However, with mobile and wireless devices, context is less predictable on the design and use of computer systems.

Mobile applications can vary continuously because of changing circumstances and different user needs (Tarasewich, 2003). The object of mobile learning design is inseparable from the design, the context or activity of use. Mobile technologies present new challenges to both theory and design of their applications such as mobile learning (or m-learning). Activity theory seems to provide appropriate abstractions and concepts to analyse design activity for m-learning. Tarasewich has developed a three-category context model as shown in Figure 1.

Figure 1 Context model from Tarasewich (2003)

Environment is concerned with the properties of objects in the physical environment. Participants include the status of the user(s) and other participants in the environment. Activities cover user(s), participants and environmental activities. The model also includes interaction or relationships between participants, activities and the environment. Devices and applications can adapt themselves automatically to changing contexts.

Tessmer and Richey (1997) also describe the context as being composed of levels as well as factors. According to Tessmer and Richey, context is therefore a multi-level body of factors in which learning and performance is embedded. It is not the additive influence...
of discrete entities, but rather the simultaneous interaction of a number of mutually influential factors. Factors such as physical, social and instructional aspects interplay to influence learning. Context plays an important role in learning. Firstly, learning does not occur in vacuum. Context is an influential and inevitable part of every learning experience. It is not possible to separate or avoid the context in which we operate. All cognition and reasoning is situated (Greeno, 1989).

Successful instructional design must be situation-specific (Tessmer and Richey, 1997). As in situated learning or a constructivist environment, cognition is defined and shaped by its relation to a given context. This means that we must not only learn in context but also by context (Snow, 1994). Context is multifarious, complex and enveloping (Tessmer and Richey, 1997). A given context has different aspects, such as social or political as well as cultural. A contextual factor may have different types of contextual impacts that differentially mirror the types of context that exist in a situation.

Knowing is an activity that is co-determined by the individual and the environment (Brown, Collins and Duguid, 1989). It is impossible to separate the learner, the material to be learned and the context in which the learning occurs. Knowing always occurs in a context. According to Barab and Duffy (1999), ‘knowing about’ refers to an activity – not a thing. It is always contextualised. Knowing about is reciprocally constructed within the individual – environment interaction. It is not objectively or subjectively created. Knowing and contexts are co-constituted, and learning is fundamentally connected with and constitutive of the contextual particulars through which it occurs (Barab and Krisner, 2001).

There may be multiple contexts in a given learning or performance. All of them influence the nature of learning. There are several techniques and tools that have been developed to support taking the context into account in the design of computer technologies. These include task analysis (Dix et al., 1998), participatory design (Bødker et al., 1988) and contextual design (Holtzblatt and Beyer, 1993). Kaptelinin, Nardi and Macaulay (1999) criticise that existing approaches to context design are mostly bottom-up. These authors suggest that a more useful approach is to have a bottom-up complemented by a top-down approach. They have suggested using activity theory as an ideal theoretical framework for describing the structure, development and human work and praxis, that is, an activity in context.

Context is an important instrument for promoting the achievement of cognitive and behaviour goals. However, despite the importance of context, there is very little formal consideration in any of the learning design models (Tessmer and Richey, 1997), yet context is everything to instructional design (Jonassen, 1993).

Although researchers have tried to use different types of context in their applications, context-aware applications have utilised only isolated subsets of their context such as location or a device’s state (Kaenampornpan and O’Neil, 2004). According to these authors, a truly context-aware system requires a holistic approach that takes into account the interrelated types of context and relationships among them. This requires a modelling approach that can take this complexity into account. According to Kaenampornpan and O’Neil, these relationships are important in order to use the context to represent the world of the user and to assist the system’s understanding of the user’s activities and intentions because humans assimilate multiple items of information to perform everyday tasks. The relationship between each element should also be clarified to define the reasoning process. Kaenampornpan and O’Neil (2004) have proposed activity theory be used as a model to clarify the relationships between different elements of the context and at the
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same time cover key elements that influence human activity in a mobile application. These relationships between different elements of context can affect the efficiency of context-aware applications. They can be used to better understand the user’s activities and intentions.

It is the author’s belief that by improving the computer’s access to context, we can increase the richness of communication in human–computer interaction and make it possible to produce more useful computational devices. Context plays an important role both in learning and in the design of mobile technologies. However, contextual factors are elusive and difficult to pin down (Brown and Duguid, 1994). It is the author’s belief that activity theory offers us a powerful tool to model and understand the design of a mobile learning environment that is usable and contextual. A brief review of activity theory and its benefits for mobile design are given in Section 3.

3 A brief review of activity theory

Activity theory originated in the former Soviet Union as a cultural, historical psychology by Vygotsky (1978) and Leont’ev (1978). It focuses on understanding the human activity and work practices. It incorporates the notions of intentionality, mediation, history, collaboration and development (Nardi, 1996). The unit of analysis is the entire activity. The principles and components of activity theory have been used as analytical tools for many different subjects. These include: human–computer interaction (Kuutti, 1996), information systems (Bødker, 1991), interface design (Bødker, 1990), communities of practice (Engeström, 1993), education (Engeström, 1987), etc.

An activity consists of a subject and an object, mediated by a tool. A subject can be an individual or a group engaged in an activity. An activity is undertaken by a subject using tools to achieve an object (objective), thus transforming it into an outcome (Kuutti, 1996). Tools can be physical such as a hammer or psychological such as language, culture or ways of thinking. Computers are considered as special kinds of tools (mediating tools) (Kaptelinin, 1996). An object can be a material thing, less tangible (a plan) or totally intangible (a common idea) as long as it can be shared by the activity participants (Kuutti, 1996). Activity theory also includes collective activity, community, rules and division of labour that denote the situated social context within which collective activities are carried out. Community is made up of one or more people sharing the same object with the subject. Rules regulate actions and interactions with an activity. Division of labour informs how tasks are divided horizontally between community members. It also refers to any vertical division of power and status.

Activities always take place in a certain situation with a specific context (Engeström, 1987). Engeström (1987) formulated activity context as a network of different parameters or elements that influence each other. Figure 2 shows Engeström’s model (1987) of an activity system.
Figure 2  Basic structure of an activity

Just as artefacts or tools mediate the relationship between subject and object, rules mediate the relationship between subject and community. Similarly, division of labour mediates between community and object. Activity theory is often associated with three levels describing the hierarchical structure of activity. Each activity is conducted through actions of an individual, directed towards an object or another object. An action is a single task with a goal performed to achieve a self-contained, pre-conceived result relevant to the overall activity. Actions are performed by a sequence of operations. Operations are the work functions or routines with each action determined by the actual conditions and contexts of the action during its performance.

Activities in activity theory are not static or given, but are dynamic. They are changing and developing. This development takes place at all levels: new operations are formed from previous actions when participant’s skills are increasing. Correspondingly at the action level, the scope of new actions is enlarging. Totally new actions are also enacted, experimented and adapted as responses to new situations or possibilities encountered in the process of transforming the object. At the activity level, the object/motive itself is also reflected, questioned and perhaps adapted, reacting to larger changes and other activities (Kuutti, 1996).

Because activities are not static but more like nodes crossing hierarchies and networks, they are influenced by other activities and other changes in the environment. External influences change some elements of activities causing imbalances between them (Kuutti, 1996). Contradiction is the term given to misfits within and among elements, among different activities or different developmental phases of the same activity. They manifest themselves as problems, ruptures, breakdowns, clashes, etc. Activity theory sees contradictions not as problems but as sources of development. Activities are virtually always in the process of working through contradictions that subsequently facilitate change.

The concept of contradiction is important in activity theory. It provides a simple analytical tool for analysing the contextual design in mobile learning. Engeström analyses how contradictions, both internally in a considered central activity and between the central activity and related activities, are the driving forces in development. According to Engeström (1987), any activity system has four levels of contradictions that must be attended in the analysis of a working situation. Level 1 is the primary contradiction. It is the contradiction found within a single node of an activity. This contradiction emerges
from tension between use value and exchange value. It permeates every single corner of
the triangle and is the basic source of instability and development (Engeström, 1987).
Primary contradiction can be understood in terms of breakdowns between actions or sets
of actions that realise the activity. These actions are poly-motivated. This means that the
same action can be executed by different people for different reasons or by the same
person as part of two separate activities. This poly-motivation may be at the root of
subsequent contradictions.

Secondary contradictions are those that occur between the constituent nodes. For
example, between the skills of the subject and the tool he/she is using, or between rules
and tools. Tertiary contradictions arise between an existing activity and what is described
as a more advanced form of that activity. This may be found when an activity is
remodelled to take account of new motives or ways of working. Quaternary
contradictions are contradictions between the central activity and the neighbouring
activities, e.g. instrument-producing, subject-producing and rule-producing activities.

In our example, the student who is working on the project belongs to the community
that has rules, e.g. to learn specific subject with certain curriculum. To perform his/her
work, he/she uses the artefacts that the university makes available such as mobile
devices, notepads, books, internet, etc. Activities that are supported by mobile devices are
directed to specific goals. The goals guide how the student acts and also determines the
structure of the activity. The structure is organised in a hierarchical-sequential way with
goals, sub-goals and actions. The mobile device acting as artefact has to meet all the
goals and sub-goals and also has to mediate all related actions. The actions are not
isolated, but integrated in a social context related to the activity community and its rules.
Users of the mobile device are characterised with respect to their activity goals and their
roles.

3.1 Why activity theory is used for mobile learning design

There are several benefits of using activity theory for the design and understanding of
mobile learning environments. Learning is fundamentally situated and socially mediated
(Engeström, 1987; Lave and Wenger, 2000). Vygotsky (1978) depicts learning as an
interaction with more capable peers, helping the learner through the zone of proximal
development. There is a general relation between learning and development (Vygotsky,
1978). Vygotsky’s notion (1978) of mediation, where a more competent peer or adult is
viewed as assisting performance, bridging the gap between what the students knows and
can do and what the student needs to know. Vygotsky called this the Zone of Proximal
Development (ZPD). ZPD is the distance between the actual development level as
determined by independent problem-solving and the level of potential development as
determined through problem-solving under adult guidance or in collaboration with more
capable peers.

It is through the interaction with other learners and the teacher, mediated by mobile
technologies, that the ZPD emerges. Learning is not a neat transfer of information, but a
complex and often messy network of tool-mediated human relationships that must be
explored in terms of social and cultural practices that people bring to the uses of tools
they share (Russell, 2002).

Lave and Wenger (2000) depict learning as a legitimate peripheral participation in a
community of practice, where novices gradually move from the periphery, through
increasing participation towards the centre of mastering participation (Bødker and
This situated and social nature of learning from activity theory means that we need to be concerned with the context of use. Context comes into the picture through past experiences of users, and through the meaning that the artefact represents to the user (Bødker and Petersen, 2000).

Activity theory is ideal for analysing Constructivist Learning Environments (CLEs) because the assumptions of activity theory are very consonant with those of constructivism, situated learning, distributed cognition, social cognition and everyday cognition that underlie CLEs (Jonassen and Land, 1999). Individuals rarely perform activity on their own. Human activities always exist in a social context (Engeström, 1987). Individuals involved in a particular activity are simultaneously members of other activity groups that have different objects, tools and social relations. Activities are complex and introduce that required collaborative effort. Besides horizontal activity systems, there are dynamics that underlie any activity (verticalness) (Rohrer-Murphy and Jonassen, 1999). Each component of an activity is the result of other activities that produced it.

In this perspective, mobile technology is not perceived as the object of learning but as a tool to support students’ learning activities. Taking this view allows us to develop more useful learning environments and interpretations of students’ experience in these experiments than if we maintain a dualistic tradition. Only through acknowledgement of the distributed nature of knowing can meaningful learning contexts be fostered. Thus knowing and learning are perspectives of systems, not individuals. This means that in distributed cognition, individual functioning is considered to be distributed across and situated within the transaction of subject, available tools and community contexts with the division of labour or roles in which the entire systems, not individual or environmental components, are the minimal unit of analysis (Barab and Plucker, 2002). This distributed cognition fits well with the theoretical perspective of activity theory (Engeström, 1987).

Collaborative learning using mobile technologies is situated within and between activities. An activity can also be conceived as a system of distributed cognition (Hutchins, 1996). In constructivist learning, knowledge is constructed and is meaningful only within a particular community. A shared collective mind is developed over time in such a community. A collective mind is formed when people in close relationships enact a single memory that is complete with differentiated responsibilities for remembering different portions of a common experience (Weick and Roberts, 1993). The division of labour plays an important role in the development of the collective mind (Stein and Zwass, 1995).

The aim of activity theory is to understand the unity of consciousness and activity. It incorporates strong notions of mediation (activities mediated by artefacts, both internal and external), history (activity changes and develops so a historical analysis is needed to understand the current state) and collaboration (an activity is carried out by an individual to accomplish some desired outcome, within a community of other individuals controlled by a set of rules).

According to Rohrer-Murphy and Jonassen (1999), current approaches are inappropriate for designing CLEs because the epistemic beliefs of CLE are fundamentally different from traditional instruction. They suggested that activity theory could be used as a powerful framework for analysing needs, tasks and outcomes for CLEs. The author concurs with them that activity theory serves as a useful framework for understanding the totality of context of human activity. Activity theory is particularly
suitable for dealing with the context of design of a CLE. Rohrer-Murphy and Jonassen have developed an activity theory framework for analysing CLEs (Rohrer-Murphy and Jonassen, 1999).

Describing elements of the activity describes the context of that activity. In activity theory, activity is a precursor to learning. Knowing can only be interpreted in the context of doing (Rohrer-Murphy and Jonassen, 1999). Individual actions are always situated in a meaningful context and are impossible to understand in isolation without the meaningful context as the unit of analysis (Kuutti, 1996). An activity always contains various artefacts such as procedures, signs, instruments, methods and laws, etc. through which actions on objects are mediated. Artefacts are created, manipulated and translated during the development of the activity and carry the historical aspect of the development. They are also the outcomes of previous actions on objects (Bødker, 1997).

In activity theory, all activities are mediated by culturally defined tools. Because activity is mediated, this has important implications for mobile learning. It redefines the nature of learning. Instead of viewing learning as the rational abstraction of mental representation from one’s own experience, learning based on the activity theory is now re-conceptualised as learning to participate in a cultural practice (Bernard and Enyedy, 1999). Instead of designing learning based on teacher-centred or student-centred approaches in an activity theory perspective, students move through the activities and progress from being partial participants, who are heavily dependent on the material mediation of tools, to full participants, who are able to more flexibly use the cultural tools of the narrative practice (Bernard and Enyedy, 1999).

Another benefit of applying activity theory to mobile collaborative learning is concerned with the interface of the application. The interface of the mobile learning device is in constant development, changing the appearance as the user and use context develops. In the activity theory perspective, the interface and the computer artefact, such as the mobile device, are mediators of learning. Activity theory also assumes an asymmetric relation between people and things, in contrast to traditional symmetric relations offered by cognitive science or other computer science approaches, where computer programs and human behaviours are modelled using the same language and methods. Activity theory places computer applications, i.e. our mobile learning, as mediator of human activity (Bødker and Petersen, 2000).

Instead of designing mobile learning applications in isolation, using activity theory enables us to make important features of human endeavour to stand out through the hierarchical structure of activity. This allows us to focus on the context of use. Computer artefacts can only be understood in their context of use, as embedded in meaningful activity.

An activity is not a homogeneous entity. It comprises a variety of disparate elements, voices and viewpoints (Engeström, 1990). The multiplicity can be understood in terms of historical layers. Activities are not static or rigid, they are constantly evolving. To understand a phenomenon means to know how it is developed into its existing form (Kaptelinin, 1996). This applies to all the elements of an activity. The current relationship between subject and object includes a condensation of the historical development of that relationship (Kuutti, 1996).

History is also important because it is not simply an event in the past but also is alive in the present and may shape the future. The structures and behaviour of today’s learning reflect the culture and circumstance-specific historical development (McMichael, 1999). Historical analysis allows existing and emerging organisational structures to be examined
as the result of their evolutionary development, sometimes intentional and others not. This means that we must also describe and analyse the development and tensions within the activity system.

It is the author’s belief that by attempting to improve the user interaction by exploiting information relating to users, devices and environments through the notion of awareness using activity theory can bring about effective mobile learning. Context awareness plays a crucial role in reducing the user’s explicit input. Activity theory offers an ideal framework for the design of context-aware systems by providing guidance on what elements of context to take into account. It can also support the implementation process and both user and system-driven adaptability at run time.

In addition, this approach enables us to interpret the context of user behaviour in the application. This enables minimisation of explicit input and becomes personalised for the individual user. Minimising explicit input would enable us to provide better usability for our mobile learners. Using activity theory enables the covering of key elements of context that can influence user activity, and the explanation of how elements influence the user’s ability in the actual situation.

4 Activity theory for mobile learning design

There are two main barriers when designing mobile applications: the restricted input techniques typically available with these devices and the increased cognitive load on users when attempting to multi-task in busy environments. Usability can suffer when there is a need for explicit input. The need for explicit input can be reduced by increased use of implicit input (Schmidt, Beigel and Gellersen, 1999). Context awareness is important for reducing the explicit input by taking advantage of changes in information relating to users, devices and environments to improve usability for mobile applications. It is vital to take context into account when designing mobile applications for context-aware systems.

Activity theory provides an ideal theoretical framework for describing the structure, development and human work and praxis, that is, an activity in context. However, one of the criticisms of activity theory is that it is somewhat abstract when it comes to actually working on a design. To make activity theory more useful and practical, Kaptelinin, Nardi and Macaulay (1999) have developed an artefact – the activity checklist. The checklist makes concrete the conceptual system of activity theory for design. It is intended to elucidate the most important contextual factors of human–computer interaction.

Activity theory provides a powerful vehicle for developing mobile learning. Firstly, it can be used as a lens to analyse learning processes and outcomes for the design of mobile learning. Secondly, it provides us the design of context-aware applications that are crucial for mobile technologies. The theory helps structure analysis, but does not prescribe what to look for. It does not offer ready-made technologies and procedures for research (Engeström, 1993).

There are two basic ideas that are central to activity theory. Firstly, the human mind emerges, exists and can only be understood within the context of human interaction with the world. Secondly, this interaction, that is, activity, is socially and culturally determined. These ideas are elaborated in several principles that have important implications for the design of mobile learning. An activity-based approach to mobile
learning is developed by the author, based on the work of Rohrer-Murphy and Jonassen (1999), Bødker (1996), Kaptelinin, Nardi and Macaulay (1999), Kaenampornpan and O’Neil (2004) and Engeström (1987). Principles and ideas from these different authors are incorporated in order to address the various issues such as context, user interface, CLE analysis, activity systems, development and contradictions in mobile collaborative learning.

The remaining part of the paper shows how the principles of activity theory based on the above-mentioned work are used to design a mobile learning environment. The case study used is based on the design of a mobile learning environment for students to construct a knowledge management system for the construction industry. Students working as team were expected to solve the problem. Each student was given a handheld PDA to use for collaborative work. Principles from activity theory are used to design the learning environment and the context of use. The methodology consists of steps and sub-steps as follows:

4.1 A framework for designing mobile learning

4.1.1 Step 1 Clarify of purpose of the activity

The first step in the design is to clarify the purpose of the activity. It uses the object-orientedness principle of activity theory. In activity theory, learning and doing are inseparable, and they are initiated by an intention. Intentions are directed at objects of activity (Rohrer-Murphy and Jonassen, 1999). It is important to clarify the motives and goals of the activity system. The reasons are to understand the context within which activities occurred to reach a thorough understanding of the motivation for the activity being modelled and any interpretations of perceived contradictions. Techniques that can be used include observations, interviews and document analysis, etc. The information obtained will guide the construction of the problem space (deal with learning).

1. Generate a list of problems that students typically deal with. What are the participants and groups involved in the successful completion of the activity?
2. When and where do these problems normally occur?
3. Generate a concise list of subject-driven motives and goals for each of the groups involved that might drive the activity.
4. Who set those expectations of the learners?
5. What might contribute to the dynamics of the situation under review?

Deal with interface design

Human beings live in a socio-cultural world. They achieve their motive and goals by transformation of objects into outcomes in their environment. This section identifies the objects involved in target objects involved in target activities and constitutes the environment of the use of target technology (Kaptelinin, Nardi and Macaulay, 1999).

1. What resources are available to the parties involved in the design?
2. What tools and materials are accessible?
3 What rules, norms and procedures are regulating the social interaction and coordination?

4 Is targeted technology integrated with other tools and materials?

5 What are the roles of existing technology?

4.1.2 Step 2

A collective activity system is taken as the unit of analysis, giving context and meaning to seemingly random individual events. The first step is to translate the learning setting into the activity system by entitling its collective object of activity, different (groups of) actors who are involved in the learning environment, the way in which the labour has been divided among these actors, the mediating artefacts that are being used by the actors, the rules that apply between the actors involved, etc. (Figure 2). The components of activity systems are initially described from the perspective of one of the (group of) actors identified as the subject of the activity system.

4.2 Analyse the context for learning and use

Context is internal to people (involving specific objects or goals) and external (involving artefacts, other people and setting). In addition, there is also the location, technical and environment context concerning the mobile technologies.

Questions need to be asked include:

- How do things get done in this context?
- Why?
- Who is doing what and why?

In the design, it is important to understand how things get done in a context and why. This is because different contexts impose different practices. To analyse the context, we need to know the beliefs, assumptions, models and methods commonly held by group members, how individuals refer to their experiences in other groups, what tools they found helpful in completing their problem, etc. In addition, there are also external or community-driven contexts. These include issues such as (Rohrer Murphy and Jonassen, 1999):

- What type of limitations is placed on the activity by outside agencies?
- How are tasks organised among the members of the group working towards the object?
- What is the structure of the social interaction surrounding this activity?
- What activities are considered to be critical?
- How flexible is the division of labour? How well can these roles and their contributions to be evaluated?
What formal or informal rules, laws or assignments guide the activities in which people engage?

Is there a difference between implied rules and those formally stated?

4.2.1 Clarify the relevant context within which activities occur

Questions to ask include:

- What are the activities, goals and sub-goals to be supported by the learning environment?
- Who are the users or group members involved?
- Where do problems occur?
- What is the purpose of the activity/actions for the users?
- What is the user trying to achieve?
- How do user’s activities fit into the objectives of learning?
- What are the expectations about the outcomes?
- What are the beliefs, assumptions, models and methods that are commonly held by the working groups?
- How do individuals refer to their experiences in other work groups?
- What tools do users find helpful in completing these projects: In different contexts?

4.2.2 Analyse the activity system using Engeström’s activity diagram

The following scenario is used to help identify key elements of the activity context approach:

David is an undergraduate student. He is working collaboratively on a project with other members of the group to solve a problem. He is currently in the library. The phone rings and he is asked by Anne to find out the information about semantic web for his project. Anne is working in the project room with John and Alan. They need the information quickly so that they can get on with the design of the solution. David promises to send the information back as soon as possible. Using the above scenario, the activity system depicted is shown in Figure 3. The elements in the activity theory cover the key elements of context in David’s learning. Although time is a crucial part of context, the current diagram does not reflect this. It is important not only to include current time but also past time (a history element of context) and future time. (This allows for the prediction of user’s action from current context.) To do this we adopted the context modelling of Kaenampornpan and O’Neil (2004) as shown in Figure 4.
Figure 3  Classifying context of David’s learning using activity theory.

Subject (User)
Who are the people participating in the activity system? What are their roles?
What is the outcome of the activity?
What are the criteria for evaluating the activity?
What are the rules (implied and formal) of the members of the group of learners?
What is the division of labour within the activity system?
Subject-user, in our case the learner (information about learners and action) and physical environment of the learner

Tools
What tools are used in this activity? Are they available to learners?
What are the physical tools used to perform the activity? What are the psychological tools used? (Methods, procedures, techniques, languages, etc.)?
How have the tools changed over time?
What models, theories or methods guide the activity?
How learners used the tools?

The main tool here is the mobile device used by the learner, and any other non-computing tools such as books, manuals, notepads, internet, etc.

Object
What is the expected outcome of the activity?
What criterion is used to evaluate the outcome of the activity?
How will the object move the learners completely towards fulfilling the intentions of the individual?

User intention, objective including raw material that will be transformed to achieve an outcome. In our case, the learning of a particular problem.
Activity theory for designing mobile learning

Community
To what extent does the subject–work community impact the subject–object pair?
What is the structure of social interaction surrounding the activity?
How might conflicts that originate in other communities affect learner interaction?

Social and physical environment of other users that might have influence on the user's activity.

Rules
What are the formal and informal rules that guide the activities learners are engaged in?
How might those rules have evolved?

Can be explicit or implicit such as rules of engagement in the use of mobile devices, university regulations, etc.

Division of labour
Who traditionally have taken on the different roles? How does that affect work group activities or breakdowns?
How do those roles relate to other roles?
What factors drive the role change?

Roles of user or learner according to the relationship between them and community or user's location. Who can perform which task?

Figure 4   Representing the history of activity theory

4.2.3 Analyse the activity structure

For each activity, decompose the activity into actions and operations (analyse the activity structure). An important key process in the learning system is to analyse the activity structure (all of the activities that engage the subject) that defines the purpose of the activity system. The hierarchy of activity, actions and operations describe the activity structure.

This step involves defining the activity such as:

- How is work being done in practice?
- How has the work (actions and operations) transformed over time?
- What historical phases have there been on the work activity?
- What are the goal motives of the activity and how are they related to other concurrent goals?
- For each activity, what actions can be performed and by whom?
- For each action, observe and analyse the operations that the subjects perform.

For the interface aspects of the learning environment, the following issues should be addressed. Understanding the use of technology should start with the identification of goals of target actions that are relatively explicit and then extend the scope of analysis both up (to higher level actions and activities) and down (to lower level actions and operations).

- Who are the people that will use this mobile learning?
- Goals of target actions.
- People involved in the design process.
- What are the basic limitations of the current technology?
- Are there conflicts between different goals of users?
- Criteria for the success or failure of achieving goals.

4.2.4 Externalisation/internalisation (from Kaptelinin, Nardi and Macaulay dealing with interface issues)

The activities include both internal and external components, which can transform into each other. The mobile technology should support both internalisation of new ways of action and articulation of mental processes, when necessary, to facilitate problem-solving and social coordination.

- What are the components of target actions that are to be internalised?
- What are the time and effort needed to learn how to use the technology?
- Is the whole life cycle from goal setting to the final outcome taken into account and supported?
- Does the system help to avoid unnecessary learning?
Does the system provide problem representations in case of breakdowns that can be used to find a solution or formulate a request for help?

Is externally distributed knowledge easily accessible when necessary?

Are there external representations of user’s activities that can be used by others as clues for coordination?

4.3 Historically analyse the activity and its constituent components and actions

It is important to analyse the development of the activities such as the nature of changes that occur in different historical phases of the activity. In addition, it is also necessary to analyse the mediators and their transformation over time in order to provide important historical information about how and why activity systems exist as they do. Thus it is important to examine the role that persistent structures, such as artefacts, instruments and cultural values play in shaping the activity (Rohrer-Murphy and Jonassen, 1999).

Activities undergo permanent developmental transformations. Analysis of the history of target activities can help reveal the main factors influencing the development (Kaptelinin, Nardi and Macaulay, 1999). Analysis of potential changes in the environment can help anticipate their effect on the structure of target activities.

What are the consequences of implementing the target technology on target actions? Did the expected benefits actually take place?

Does the system show increasing benefits over the process of its use?

Are there negative or positive side effects associated with the use of the system?

How are the transformations of existing activities into future activities supported with the tools?

What is the history of implementation of new technologies to support target actions?

What are the anticipated changes of target actions after the new technology is implemented?

In order to model the time or historical aspect of the activity, we have adopted the context modelling of Kaenampornpan and O’Neil (2004).

<table>
<thead>
<tr>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrete time – a history of context sets when activity occurs. (System does something to serve the user – learner.) We are only interested in recording the context when the activity occurs.</td>
</tr>
</tbody>
</table>

4.4 Search for internal contradictions as the driving forces behind disturbances, innovations and change of activity system

Inner contradictions of the activity systems shall be analysed as the source of disruption, innovation, change and development of that system. By identifying the tensions and
interactions between the elements of an activity system, it is possible to reconstruct the system in its concrete diversity and richness, and therefore explain and foresee its development (Engeström, 1999).

4.4.1 Analyse the Contradictions

- What are the dynamics that exist between the components of the activity system?
- Are there contradictions or inconsistencies within the needs of these various components of the activity system?
- What are the interrelationships that exist within the components of the system?
- How have these relationships changed over time?

Several types of contradictions are identified in our mobile learning design as shown in Figure 5. These are:

- Potential primary contradictions in the mobile learning environment
  1. At the object node, there is tension between the types of learning. It can be traditional or acquisitional approach vs. constructivist learning.
  2. At the tool node, there is the issue of using mobile technologies compared to traditional classroom.
  3. At the rule mode, there is the question of assessment regarding individual marks against group work projects.

- Potential secondary contradictions within the mobile learning environment
  4. There is tension between the rules (use of mobile technology), which will have an effect on the division of labour. The tension exists because it is not clear what rules or regulations determine who should be involved in the project.
  5. There are different perceptions of the activity object, which reflects the heterogeneous nature of the subject group and their object (e.g. learning as knowledge construction or information gathering).
  6. There is also tension between community (society) and the object node (learning). Society would like to have problem-solving and thinking skills; students are generally interested in passing examinations.

- Potential quaternary contradictions between mobile learning activity and other co-existing activities such as traditional teaching activity and technology activity.
  7. There is fundamental contradiction between the use of mobile technology for learning and traditional classroom teaching.
  8. There is also tension between the availability of technology and the use of mobile learning environment.
5 Conclusion

Although mobile technologies offer the potentials for learning, there are usability problems in the design of these devices because of their small, limited input and dynamic context (Kjeldskov, 2002). There is still very little understanding of how mobile technologies can be designed to best support collaborative learning. Collaborative learning using mobile technologies comprises socio-technical, economic and historic facets. It should be studied within the context in which it is deployed.

Activity theory has been successfully used to analyse human–computer interaction such as interface and Computer-Supported Collaborative Learning (CSCL). It can be used to better understand distributed learning. A successful mobile application depends on the context of design. Activity theory can help designers to better understand the social and material relations that affect complex human learning and learners’ interaction with others as mediated by tools. This is because activity theory provides a philosophical framework for understanding collective human work activities as embedded within a social practice (e.g. an institution) and mediated by artefacts, such as mobile technologies.

Although activity theory offers benefits for designing mobile learning environments, it also has limitations. The key limitation of this approach is also its key strength. Firstly, the researcher involved in it must have a complete understanding of the activity system under observation, including the dynamic interplay of all the units of the activity system (McMichael, 1999). Secondly, the difficulty faced by researchers in unravelling activity systems. Thirdly, the difficulty of distinguishing between the levels of activity, actions and operations.

It is the author’s belief that the benefits outweigh these limitations. Using the activity system as its unit of analysis, activity theory avoids simple causal explanation of mobile learning design by describing an institutional setting as an ensemble of multiple, systematically interacting elements including social rules, mediating artefacts and division of labour. It also explicitly perceives an activity as a dynamic phenomenon in which not only consensus and stability but also conflicts, breakdown and discontinuities
play a crucial role. The process of context and the dynamic transformation of objects into artefacts can be taken into account. This approach also takes the perspectives of different actors of an activity system. However, further work is still needed for it to be used as a robust design method. For effective use of activity theory for designing context-aware mobile applications, it is important that research time be long enough to understand the objects of activity, the changes of those objects over time and their relations to objects in other settings. There should also be commitment to understanding things from the users’ viewpoint. This means that there should be a phased approach to the design and evaluation of technology use, such as mobile devices for collaborative learning.

References


