A Theory-ology of Mobile Learning: Operationalizing Learning Theories with Mobile Activities

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Abstract. Theory is often neglected when planning and analysing mobile learning projects, beyond perhaps a brief but unexamined list of learning theories in the introductions to articles. Theory is, however, important since it underpins the expectations of meaningful learning outcomes that any given mobile learning activity should have. Attention has been paid in the past to theoretical frameworks that might usefully be applied to mobile learning. Underpinning these frameworks are a specific set of learning theories, but such is the variety of mobile learning that no single theory, or set of theories, should be assumed to be fully embodied in any single activity. The aim of this paper is to identify, from the literature, the key underpinning theories of mobile learning, then to examine how these might be called into play in varying combinations, depending on the nature and intent of specific types of mobile learning. The identification of these theories is grounded in their links to mobile affordances. An approach to analysis is suggested that could prove a useful tool in designing and evaluating mobile learning activities with due consideration of their embodied learning theories. This approach is briefly explained through two contrasting examples.

Keywords: mobile learning, learning theory, affordance, framework

1 Introduction: Theories of Learning

A learning theory can be described as a conceptual framework used to understand and frame how information is absorbed, processed, and retained during learning (Luis & D'Cunha, 2014). Considering how theory underpins learning activities is important to ensure appropriate pedagogical practice. This is especially important when adopting emerging technologies, such as mobile technology, to ensure that the learning, not the tool, is the driver of the activity. Since mobile learning is relatively new, there has been considerable debate about whether it is significantly different from current learning to warrant its own unique theory, or whether it is simply underpinned by a range of existing theories. Harasim (2012) notes the historical context of 20th century learning theories and questions whether new contexts and technologies require new learning theories. However, she also notes the intrinsic link between theory and teaching practice even if this is implicit, thus theory, old or new, is what we operationalise in our pedagogy. The assertion of this article is that consciously mapping appropriate learning theories to a given activity can help educators to understand and apply appropriate mobile learning and teaching practices.

Learning theory addresses a range of factors, including, from a behavioral perspective; how such changes become relatively permanent, whether the change is immediate, or potential, what role experience plays and what aspects of reinforcement are present (Olsen and Hergenhahn, 2013). There are many learning theories, most of which have been developed over the last century or so. There are also many categorizations that may be applied to these theories, but we might make a distinction between those that look at intrinsic factors, such as the cognitive processing that goes on inside the brain, and those that look at extrinsic factors, such as context, social interaction and (increasingly digital) learning tools. Some theories are grounded in experimental methods, such as classical and instrumental conditioning, while others are less rigorously validated and open to more interpretation (e.g connectivism.) Some of these fields are so broad as to require considerable explanation in each case to define which specific approach is being taken (e.g. constructivism).

Early learning theories tended to focus on aspects of behavioural conditioning, such as Pavlov's classical conditioning, where stimulus leads to response, and Skinner's instrumental conditioning, where behaviour leads to reinforcement (Olsen and Hergenhahn, 2013). Whilst such approaches might seem somewhat mech-

anistic, the concepts of rapid feedback embodied within them are important concepts in helping learners to work at their own pace. The idea of reinforcement having a benign, positive impact was underlined by Thorndike, who emphasised positive reinforcement over negative punishment (Olsen and Hergenhahn, 2013.)

Not all of the early learning theorists were experimental behaviorists. Dewey (1933) stressed the value of outdoor education and hands-on, experiential learning, while Vygotsky (1978) emphasized the social role of learning, with the help of 'more knowledgeable others' (which might these days include digital sources) in the Zone of Proximal Development. Other theorists also looked at the learner's environment, for example Piaget (1955), who believed that educational environments should provide the opportunity for discovery learning. More recently, Brown, Collins and Duguid (1989) asserted that learning is embedded in the activity, context and culture in which it is learned. The importance of learning with others is central to the Community of Practice (Wenger, 2000) which similarly emphasizes context and culture but also regards the authentic domain of the learning community as important. These aspects are to some extent brought together in distributed cognition, where situations, tools and communities distribute knowledge (Hutchins, 1995).

While most learning theories are grounded in 20th century thinking, in the 21st century we have seen the rise of new theories such as connectivism (Siemens, 2004), which has been proposed as 'a learning theory for the digital age.' The concept of connectivism is based on the idea that Internet technologies have created new opportunities for people to learn and share information across networks. As one example of this, Siemens has engaged with the MOOC movement (McAuley, Stewart, Siemens & Cormier, 2010).

While all of the theories above apply to learning in general, in this article we ask in what ways they apply to mobile learning. Further, we consider whether there are any theories that have particular applicability to understanding how mobile learning works in practice. In the following sections we begin to explore these questions.

Frameworks and Theories of Mobile Learning

In addressing whether we need a new theory of learning for the mobile age, Sharples, Taylor and Vavoula (2010, p4) identified five clear criteria that should underpin mobile learning theory and differentiate it from other existing learning theories:

- is it significantly different from current theories of classroom, workplace or lifelong learning?
- does it account for the mobility of learners?
- does it cover both formal and informal learning?
- does it theorise learning as a constructive and social process?
- does it analyse learning as a personal and situated activity mediated by technology?

This is a broad set of criteria and it is a matter of debate to what extent they have been met by the proposals of researchers, though some theoretical frameworks specific to mobile learning have been outlined. These have included Sharples, Taylor and Vavoula's (2006) framework for analysing mobile learning, Laurillard's (2007, 2013) Conversational Model, Koole's (2009) Framework for the Rational Analysis of Mobile Education (FRAME) and Kearney, Schuck, Burden and Aubusson's (2012) mobile pedagogical framework. However, these frameworks are not learning theories *per se*. Rather, they are ways to evaluate and frame mobile learning activities within the ubiquitous landscape of mobile learning.

Underpinning all of these frameworks are a range of pre-existing learning theories. This multiplicity of underlying theory is highlighted by Laurillard (2009), who identifies the learning process as having elements of 'instructionism' (i.e. behaviourism), constructionism, social constructivism and collaborative learning (or 'social constructionism'). However, the focus and context of a learning activity will lead to different levels of each element as each one is appropriately applied. It can thus be questioned if one theory or framework can truly capture the dynamic and varied nature of mobile learning. Mobile technologies lend themselves to certain activities, and they might be only one element of a larger learning experience; mobile activities are often integrated as part of blended learning contexts, including face to face classroom interactions. Therefore, it is important to clearly understand the learning activity and the proposed outcomes. Herrington and Herrington (2007) highlight that guidelines for learning with mobile technologies should be theory-informed. Clearly understanding what learning theories underpin a learning activity will help inform and ensure effective pedagogy.

Theory-ology and Affordances

One reason that a plethora of theories have been applied to mobile learning may be that mobile learning activities themselves vary considerably. In the same sense that a methodology is a collection of interacting methods, there may be a theory-ology of theories that interact in mobile learning. Which of these apply most directly to mobile learning may, perhaps, be analysed through the lens of affordances. Gibson (as cited in Bruce, Green & Georgeson, 2003) developed the theory of affordances, which says that the affordances of the environment are potential actions and interactions that the environment offers. Parsons, Thomas and Wishart (2016) identified six specific affordances from the mobile learning literature. Table 1 outlines these identified affordances and matches these to the learning theories most commonly associated with mobile learning. As indicated, there are a number of learning theories that are especially underpinned or enhanced by related affordances. We have used this link between theory and affordance to focus down from the very large number of available learning theories to a small subset that we believe provides the core theory-ology of mobile learning. These learning theories have been placed in approximate chronological order of their emergence. In Table 1 we have attempted to define the essence of these learning theories, though it is acknowledged that these summaries are, of necessity, simplifications. We use this subset of theories, comprising behaviorism, constructivism, experiential learning, situated cognition, community of practice and connectivism, in the remainder of this article. It should be noted that the examples of mobile activities are intended to be indicative rather than comprehensive, and linked with those theories that they most closely operationalise, though they may also be applied to others.

2 Mapping Learning Theories to Mobile Activities

When designing a mobile learning activity, it is important to understand how learning theory underpins the learning design. An appropriate and considered pedagogical approach will help ensure that learning is the primary and main concern and that the technology is not used for technology's sake. Multiple learning approaches may be adopted within one extended activity, so it is important to conceptually frame the learning within the targeted learning outcomes that one would expect from operationalising one or more learning theories.

The following discussion focusses on the six theories from Table 1; behaviorism, constructivism, experiential learning, situated cognition, communities of practice and connectivism. As a way of gaining deeper insights into how these theories have been applied in mobile learning, we evaluate to what extent different mobile learning experiences have exercised these theories in their designs by applying a rubric. This rubric was underpinned by the criteria identified in the Appendix. These criteria were identified from the literature as principles which frame learning design within the six chosen learning theories. For example, this scale was used to evaluate behaviourism:

1: The mobile activity does not use stimulus and response, involves no measurable outcomes, sequenced materials, feedback or reinforcement.

5: The mobile activity is wholly designed around stimulus and response, measurable outcomes, sequenced materials, feedback and reinforcement.

These results were collated into radar charts for a number of different examples. We found this exercise to be a very useful way of identifying which types of mobile learning activity operationalised which group of learning theories. To illustrate this process, we have included two contrasting examples in the following sections; the well-known Ambient Wood project (Rogers *et al*, 2002) and the mobile language app Busuu (www.busuu.com). These examples highlight two very different mobile learning activities, and we examine how learning theories have been incorporated (whether explicitly or implicitly) into each of these activities. It should be noted that this analysis was undertaken by the authors using subjective assessment of each example against our rubric-style criteria and was thus performed through an interpretive lens rather than with empirical measures. In the following discussion, the criteria referred to are taken from Table 2 in the Appendix.

Table 1. **Learning theories and the mobile learning affordances which they underpin (adapted from Parsons, Thomas & Wishart, 2016).**

Learning Theories	Examples of Mobile Activities (examples)	Mobile Affordances	Context of Use
Behaviourism *"The ideal of behaviorism is to eliminate coercion: to apply controls by changing the environment in such a way as to reinforce the kind of behavior that benefits everyone." (Skinner, cited in Sobel, 1990)*	Quizzes, in class polling, discussion and question and answers. Skills-based learning (e.g languages).	Portability Immediacy	To receive and give immediate feedback within and outside the classroom
Constructivism *"The principle goal of education… should be creating men and women who are creative, inventive, and discoverers, who can be critical and verify, and not accept, everything they are offered." (Piaget, 1988, Unpublished Paper)*	Taking Photos Recording Videos, Notes & Sound	Rich tool kit Portability	Working with physical or conceptual materials to construct new artefacts and knowledge
Experiential learning *"The process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41)*	Using experimental tools e.g. mobile device sensors, GPS QR codes, augmented reality, virtual reality	Evidence gathering Contextual, active learning Portability Communication	To gather, manage or store information and display understanding To visualise and present digital content
Situated cognition *"The activity in which knowledge is developed and deployed, it is now argued, is not separable from or ancillary to learning and cognition… Rather, it is an integral part of what is learned. Situations might be said to co-produce knowledge through activity." (Brown, et. al, 1989, p.32)*	Using tools to explore environments e.g. Augmented Reality. audio tours	Portability Contextual, active learning Outdoor environment Location awareness Communication	For movement during learning activities. To support learning outside the classroom For active learning interacting with a context.
Communities of Practice *"A community of practice can be viewed as a social learning system… In a sense it is the simplest social unit that has the characteristics of a social learning system." (Wenger, 2000, p. 1)*	Coordinating distributed messaging Social media	Communication Immediacy	For communication and/or collaboration To support learning outside the classroom
Connectivism *"Learning... can reside outside of ourselves… is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing." (Siemens, 2004, para 21)*	Sharing and communicating dynamic knowledge creation with others and networked sources of dynamic data	Interaction with the interface Communication	To explore knowledge through networked interaction with machines and other people

Example 1: Augmenting the Real World with Mobile Technology in Ambient Wood

The Ambient Wood Project was an innovative educational project involving primary school children using mobile technology to augment and explore a physical woodland environment (Dix. Finlay. Abowd and Beale, 2003). Underpinning this project was a rich set of located technologies which supported collaborative construction of knowledge (constructivist criteria 3). Mobile devices, radio frequency (RF) identification tags, movement sensors and multi-modal displays were used to trigger and present the 'added' digital infor-

mation (Rogers, et. al., 2002). The mobile devices were used to look up more information about these points of interest, as well as to take environmental readings like temperature and humidity, reflecting a typically constructivist mobile learning activity (Anand, Herrington and Agostinho, 2008). The students were engaged in active learning and had control of their mobile devices (constructivism criteria 1 and 4). However, we might regard the activities as being too directed by the embedded tools to fully engage with constructivist learning.

The project centered around pairs of children equipped with a number of devices exploring and reflecting upon a physical environment that had been prepared with a WiFi network and RF location beacons. This exploratory investigation allowed the children to build complex understandings of the rich ecological environment and lifecycles including the fragility of these habitats. The project was underpinned by experiential learning principles where the children were transforming their experience into knowledge (experiential criteria 1, 2). The children were allowed to explore and discover aspects about plants and animals living in the various habitats in the wood. The field trip was used to encourage learners to discover, hypothesize and experiment with biological processes taking place within a physical environment (Rogers, et. al., 2002) (experiential learning criteria 4 and 5).

The learning was based on exploring a physical environment, proving the authentic context and activities typical of situated cognition (criteria 1). The project enabled learners to integrate their understanding and knowledge through a dialectic process of reflecting and acting (Situated cognition criteria 1 and 4; experiential learning criteria 3), and to do so in a playful way (Rogers, et. al., 2002). The students interacting with the environment and with others through shared activities and language (situated cognition criteria 2 and 3).

Social interaction and communities of practice were encouraged to a degree. Walkie Talkies were used by the children to communicate with a remote facilitator, they were used to answer questions posed by the remote facilitator (criteria 2 and 4). Additional information could also be received by the students via the mobile devices (Randell Phelps and Rogers, 2003). They shared a domain and learned within it, but this community was short lived, confined to the scope of the activity. The connectivism component was limited by the range of networked resources and tools that were available at the time of the project, which predated the publication of connectivist theory. Nevertheless, the technologically-supported environment that supported dialogue and collaboration supported some connectivist features (criteria 2). No significant behaviorist components were identified in the learning process.

Based on this analysis it is evident that the project was underpinned, to different degrees, by five of the six learning theories focused on within this article; namely connectivism, experiential learning, constructivism, communities of practice and situated cognition, with a core focus on situated, experiential learning (Figure 1).

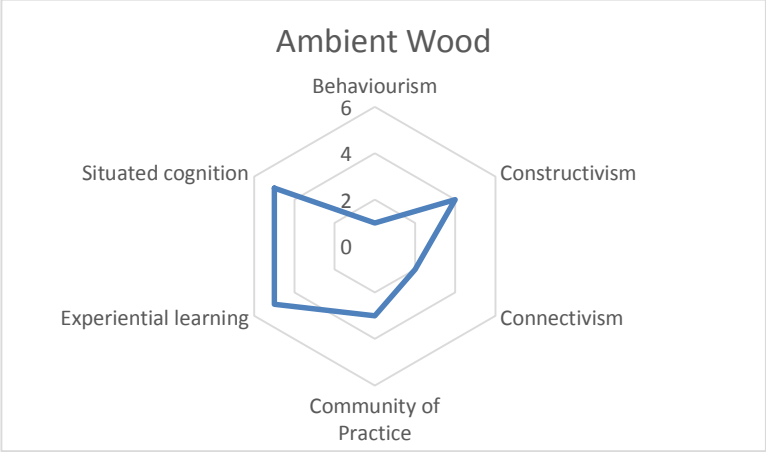

Figure 1. **Analysis of learning theory in the Ambient Wood project**

Example 2: Mobile Language Learning Apps within a Personal Learning Environment

Mobile Assisted Language Learning (MALL) is a popular topic for mobile learning applications and has been the subject of extensive research (Viberg and Grönlund, 2013). Reasons for the popularity of MALL

include personal mobility, personalised learning, social contact and collaboration (Kukulska-Hulme and Shield, 2008). Thus any exemplar chosen to explore MALL in practice should not only provide individual language experiences but support learning with others. With this in mind we have chosen the Busuu app as one example of many, because it combines both the conventional drill and practice of a multitude of language learning apps with a connectivist approach to social media and personal learning networks (Brick, 2011). Busuu is a mobile and web self-paced language learning application. The platform allows learners to practise their skills directly with other native speakers in a world-wide community of users. The application embeds interactive multimedia content with a social networking environment (Busuu, 2006). Ketyi (2013) notes that Busuu has an active and supportive community of learning, and its social networking features scored highly in a study by Liu *et al* (2013), while Gaved *et al* (2013) emphasised the impact of its feedback and progress indicators.

As with most language learning applications, Busuu is heavily underpinned by behaviourist learning principles, with the core aspect of the app focusing on drill and practice of the repetitive language activities (Storz, Maillet, Brienne, Chotel and Dang, 2012). Learners are scaffolded within their learning, where a course is broken down into learning units (behaviourism criteria 1 & 3). The learning units enable learners to practice and reinforce their learning, underpinned by the formation of habits mainly through imitation and repetition (Mitchell *et al*, 2013) (behaviourism criteria 4).

Badges are used to reinforce behaviour, show achievement (e.g. completing a learning unit or finishing a course) and encourage interaction in the community (e.g. correcting posts) (Álvarez Valencia, 2014). The use of the reward system is an example of continuous reinforcement and therefore further emphasises the behaviorist approach to learning (behaviourism criteria 2 & 5).

In addition to reinforcing and encouraging positive behaviour, badges are used to encourage collaboration and interaction between users. Some of these collaborative activities include written exercises, audio recording, and chat. These collaborative and cooperative learning are an important driving factor for encouraging and facilitating constructivist learning (criteria 3). Also underpinning the constructivist paradigm is that learning is self-paced and learners can attempt the activities at their own pace (criteria 4).

The badges also reinforce gameplay (Álvarez Valencia, 2014). The game play extends the behaviourist approach to include also elements of constructivism. Users are able to compare and rank themselves based on the number of Busuu-berries (the reward system used in Busuu) they have and with those of their friends. Learners are also able to challenge other users to complete learning units to obtain more berries. The gamification approach adopted in the application helps to "builds goal-orientation, collaboration, and competition into otherwise boring or hard activities" (Reinhardt, 2013 p 13). This approach helps make the learning more active and supports the transformation of the learning into a meaningful process (constructivism criteria 1).

Another factor within the application is its strong domain-based learning community which is an important component of communities of practice (Wenger, 2000). Users are encouraged to engage with other learners, for example by peer-reviewing others' audio-recordings of dialogues (communities of practice criteria 1 & 2). The audio recording facility allows learners to participate in a dialogue with others and more advanced learners are encouraged to support new learners (communities of practice criteria 3 and 4) so learners are encouraged to be both teacher and student. The social network allows people to correct other users' written work, making each user an expert in their own language (Garcia, 2013).

The use of social networks to connect with friends and others is an important focus of the app. Users sign up, send friendship invitations, and create groups to exchange text corrections, translations or simply to exchange some thoughts, as well practice with native speakers of a specific language (Garcia, 2013). This interaction enables and supports meaningful dialogue and collaboration, a significant component of connectivist learning theory (connectivism criteria 2). The application provides the ability for users to network with other learners to discuss and share learning (Orsini-Jones Brick and Pibworth, 2014). The features of the system enable a dynamic, technology-based knowledge community and learning network wherein students critically evaluate and synthesise concepts, opinions and perspectives (connectivism riteria 5).

Our analysis suggests that the application mainly leverages the principles of four learning theories; behaviourism, constructivism, connectivism and communities of practice, but is most strongly behaviorist and connectivist (Figure 2).

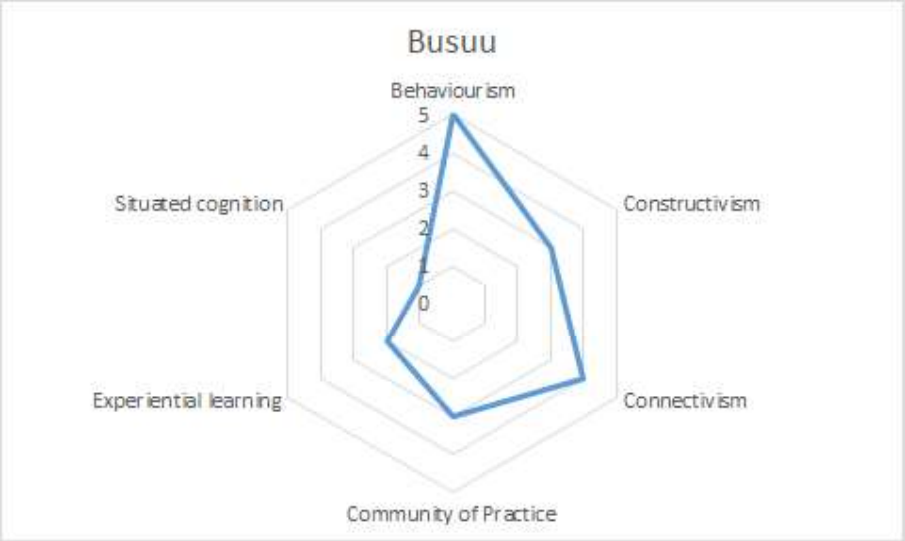

Figure 2. **Analysis of Learning Theory using the Busuu Mobile Language Learning Application**

3 Conclusion

Careful and thoughtful application of theory within a learning activity helps to ensure that appropriate pedagogy is adopted. Within mobile learning there has been considerable debate as to whether a specific learning theory is needed to capture the unique character and affordances of mobile learning, part of a broader debate about whether 21st century tools and contexts demand new learning theories to understand their characteristics and potentials. However, with our current understanding, it may be considered that applying range of existing theories, a 'theory-ology' of mobile learning, may be usefully applicable to the design of mobile learning activities. This study identified six major learning theories as being particularly relevant to mobile learning, and used them to examine two different learning contexts. These contrasting examples were chosen to highlight the wide variations in how mobile learning is applied, and also to suggest the potential change in the way that theory may be operationalised as technology develops. Our contemporary mobile app, for example, is much more capable of supporting connectivist learning than the woodland experience of a previous technology generation. Although we have so far only used this approach to analyze previous work, we believe that it could provide a useful tool to design learning activities, as well as assist in evaluation of their effectiveness, by framing their design and evaluation within a structure of interacting learning theories.

The acknowledgement that mobile learning draws on a mixed and rich range of learning theories recognises that mobile learning experiences can be extremely diverse. Mobile learning can, therefore, be a theoretically rich way of teaching and learning when the various affordances of the technology are taken into account. These affordances can help us to leverage the unique properties of mobile learning.

In this article we have emphasised the role of mixed-theory in understanding the pedagogical value of different mobile learning affordances and activities. In addition, we have explored how different learning theories can play more or less pivotal roles depending on the features of a particular learning activity. However, our intention is not only to look backward at previous mobile learning examples but to suggest that similar analyses might usefully be applied to the design of future mobile learning tools and activities. It may be that new learning theories will emerge that will provide new understandings of how we learn in an always connected mobile world of ubiquitous devices. In the meantime, existing learning theories still have much to offer.

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5 Appendix

Table 2**. Learning Theories Adopted in the Study and the Criteria Each Case Study was Measured against**

Learning Theory	Learning Design Implications (as identified in the literature based on each learning theory)
Behaviourism	1. An emphasis on producing observable and measurable outcomes in students 2. Learner tested to determine whether or not they have achieved the learning outcome 3. Learning materials must be sequenced appropriately to promote learning 4. Learners must be provided with feedback so that they can monitor how they are doing and take corrective action if required 5. Use of reinforcement to impact performance [tangible rewards, informative feedback] (Ertmer & Newby, 2013; Ally, 2004)
Connectivism	1. A stimulating and motivating learning activity that asks of and allows for learners to create artefacts in personal networks linked to other social networks 2. A technologically-supported environment that supports meaningful dialogue and collaboration 3. Learners use diverse information sources offline and online, formal and informal 4. Leveraging skills that are transferable across media, platforms and tools to expand students' learning networks 5. Developing a dynamic, technology-based knowledge community and learning network wherein students critically evaluate and synthesise concepts, opinions and perspectives (Armatas, Spratt, & Vincent, 2013; Kizito, 2016)
Experiential learning	1. Experience as foundation for learning 2. Learning as the transformation of experience into knowledge, skill, attitudes, values emotions 3. Reflection as a means of transforming experience 4. Learning through a cycle of concrete experience, reflective observation, abstract conceptualization, active experimentation, 5. Knowledge is created through the transformation of experience (Weller, 2006)
Situated cognition	1. Provide authentic context and activities that reflect the way the knowledge will be used in real-life 2. Provide access to expert performances and the modelling of processes 3. Support collaborative construction of knowledge 4. Provide coaching and scaffolding at critical times 5. Promote reflection to enable abstractions to be formed (Herrington & Oliver, 1995)
Communities of Practice	1. 'Practice' as the unifying feature of the community 2. Relationships that are grounded in information exchange and knowledge creation 3. Membership ranging from novices to old timers 4. Shared learning, which may also occur effectively at the boundaries/peripheries of the community 5. Learning can be, and often is, an incidental outcome that accompanies these social processes (Lai, Pratt, Anderson & Stigter, 2006)
Constructivism	1. Learning should be an active and meaningful process 2. Learners should construct their own knowledge rather than accepting that given by the instructor 3. Collaborative and cooperative learning should be encouraged to facilitate constructivist learning 4. Learners should be given control of the learning process and time and opportunity to reflect 5. Learning should be interactive to promote higher-level learning and social presence, and to help develop personal meaning (Ally, 2004)