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A Pedagogical Framework for Mobile Learning: Categorizing Educational Applications of Mobile Technologies into Four Types

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Abstract

Instructional designers and educators recognize the potential of mobile technologies as a learning tool for students and have incorporated them into the distance learning environment. However, little research has been done to categorize the numerous examples of mobile learning in the context of distance education, and few instructional design guidelines based on a solid theoretical framework for mobile learning exist. In this paper I compare mobile learning (m-learning) with electronic learning (e-learning) and ubiquitous learning (u-learning) and describe the technological attributes and pedagogical affordances of mobile learning presented in previous studies. I modify transactional distance (TD) theory and adopt it as a relevant theoretical framework for mobile learning in distance education. Furthermore, I attempt to position previous studies into four types of mobile learning: 1) high transactional distance socialized m-learning, 2) high transactional distance individualized m-learning, 3) low transactional distance socialized m-learning and 4) low transactional distance individualized m-learning. As a result, this paper can be used by instructional designers of open and distance learning to learn about the concepts of mobile learning and how mobile technologies can be incorporated into their teaching and learning more effectively.

Keywords: m-learning; e-learning; u-learning; transactional distance theory; cultural-historical activity theory; distance education; mobile technology

Introduction

As mobile devices are becoming increasingly ubiquitous, many researchers and practitioners have incorporated the technology into their teaching and learning environments. As Keegan (2002) anticipated, "mobile learning is a harbinger of the future of learning" (p. 9). The applications of mobile learning range widely, from K–12 to higher education and corporate learning settings, from formal and informal learning to classroom learning, distance learning, and field study. Despite the many forms of and increasing services offered by mobile learning, it is still immature in terms of its technological limitations and pedagogical considerations (Traxler, 2007). And although some researchers offer a framework for theorizing about mobile learning with conversation theory and activity theory (Sharples, Taylor, & Vavoula, 2005; Uden, 2007; Zurita & Nussbaum, 2007), instructional designers and teachers need a solid theoretical foundation for mobile learning in the context of distance education and more guidance about how to utilize emerging mobile technologies and integrate them into their teaching more effectively.

The main purpose of this study is to provide a better understanding of the characteristics of mobile learning in the context of distance education, and this is achieved by reaching three smaller goals. First, I compare mobile learning with electronic learning and ubiquitous learning. Based on this understanding of the past and current evolution of mobile learning, I describe its technological attributes and pedagogical affordances. Second, I adopt Moore's transactional distance (TD) theory and modify it by adding another dimension: two distinctive forms of distance learning that I label individualized and socialized. This establishes a total of four types of mobile learning. Third, I classify previous studies done on this topic according to the four types of mobile learning. Finally, I conclude that instructional designers and individual learners will continue to incorporate mobile technologies into their teaching and learning effectively and will pursue their educational purposes in the pedagogical framework of mobile learning.

Mobile Learning

The Evolution of Mobile Learning

Mobile learning refers to the use of mobile or wireless devices for the purpose of learning while on the move. Typical examples of the devices used for mobile learning include cell phones, smartphones, palmtops, and handheld computers; tablet PCs, laptops, and personal media players can also fall within this scope (Kukulska-Hulme & Traxler, 2005). The first generation of truly portable information has been integrated with many functions in small, portable electronic devices (Peters, 2007). Recent innovations in program applications and social software using Web 2.0 technologies (e.g., blogs, wikis, Twitter, YouTube) or social networking sites (such as Facebook and MySpace) have made mobile devices more dynamic and pervasive and also promise more educational potential.

However, it has been widely recognized that mobile learning is not just about the use of portable devices but also about learning across contexts (Walker, 2006). Winter (2006) reconceptualized

the nature of mobile learning and addressed "mediated learning through mobile technology" (p. 9). Pea and Maldonado (2006) used the term *wireless interactive learning devices* or WILD, an acronym created at SRI International's Center for Technology in Learning, to define technology that made it possible for learners to work at unique activities in ways that were previously impossible.

Peters (2007) viewed mobile learning as a useful component of the flexible learning model. In 2003, Brown summarized several definitions and terms and identified mobile learning as "an extension of e-learning" (Brown, 2005, p. 299). Peters (2007) also stated that it was a subset of e-learning, a step toward making the educational process "just in time, just enough and just for me" (Peters, 2007, p. 15). Finally, Pea and Maldonado (2006) stated that mobile learning incorporates "transformative innovations for learning futures" (p. 437).

The Evolution to Ubiquitous Learning

As Weiser (1991) stated, "the most profound technologies are those that disappear" (p. 94). He was the first scholar to define ubiquitous computing as an environment where the computer is integral but embedded into the background of daily life. Applying this concept to the education field, ubiquitous learning (u-learning) involves learning in an environment where "all students have access to a variety of digital devices and services, including computers connected to the Internet and mobile computing devices, whenever and wherever they need them" (van't Hooft, Swan, Cook, & Lin, 2007, p. 6).

In the education field, "ubiquitous computing allows us to envision a classroom in which the teacher remains focused on his or her field of expertise (e.g., math or social studies) while still utilizing technology to enhance student learning" (Crowe, 2007, p. 129). Although technological tools used for ubiquitous learning can be numerous, Crowe (2007) identified handheld computers as a key component of ubiquitous learning. Many researchers whose investigations involve handheld and mobile devices are referring to their research as ubiquitous learning (Roschelle & Pea, 2002). As the similar terms "pervasive computing" or "context–aware computing" (Moran & Dourish, 2001) emphasize,

> smaller and lighter laptops free us from the confines of the single desk . . . the distinction between communication and computation is blurring . . . on a different scale, wall-sized displays allow us to get and interact with information in an inherently social manner." (p. 87)

Figure 1 illustrates these conceptual shifts from e-learning to m-learning then to u-learning.

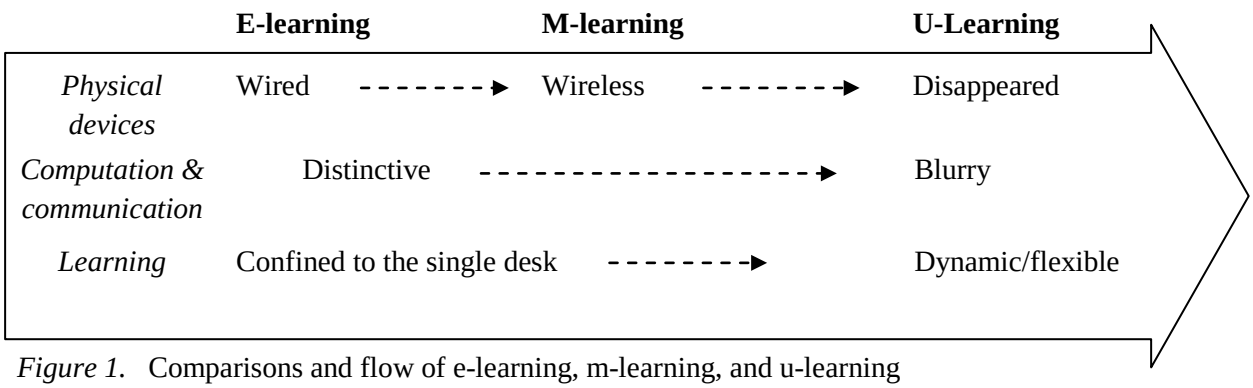

Figure 1. Comparisons and flow of e-learning, m-learning, and u-learning

Technological Attributes and Pedagogical Affordances

Mobile learning has unique technological attributes which provide positive pedagogical affordances. Pea and Maldonado (2006) summarized seven features of handheld device use within schools and beyond: "portability, small screen size, computing power (immediate starting-up), diverse communication networks, a broad range of applications, data synchronization across computers, and stylus input device" (p. 428). As Klopfer and Squire (2008) summarized, "portability, social interactivity, context, and individuality" (p. 95) are frequently cited affordances of mobile learning. Specifically, *portability* is the most distinctive feature which distinguishes handheld devices from other emerging technologies, and this factor makes other technological attributes such as individuality and interactivity possible.

Above all, this mobility enables ubiquitous learning in formal and informal settings by decreasing "the dependence on fixed locations for work and study, and consequently change the way we work and learn" (Peters, 2007). Gay, Rieger, and Bennington (2002) developed the "mobility hierarchy," including four levels of objectives that encourage the use of mobile computers in education settings. This hierarchy presents the contrasting attributes of mobile devices (see Figure 2). The focus of "productivity" (level 1) is content-intensive, whereas the focus of collaboration and communication (level 4) is communication-intensive. Level 1 aims at individual learning, and level 4 aims at collaborative learning by multiple users. Levels 2 and 3 fall into the "middle-range applications, such as personal tour guides, computer-aided instruction, database activity, mobile libraries, and electronic mail" (pp. 512–513).

As this hierarchy indicates, mobile technology has two comparable attributes. Scheduling and calendar applications are useful to increase an individual's organizational skills and self-regulative (or self-directed) learning ability; whereas, real-time chat and data sharing applications support communication, collaboration, and knowledge construction. This shows that students can consume and create information both "collectively and individually" (Koole, 2009, p. 26).

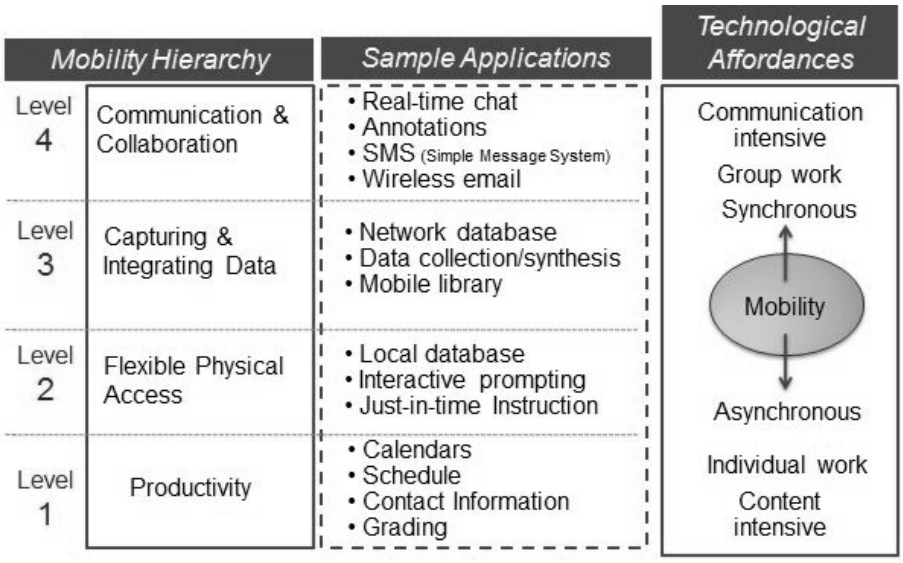

Figure 2. Mobility hierarchy, sample applications, and technological affordances. Note: Adopted from Gay, Rieger, and Bennington (2002).

Another unique attribute that mobile technology has is its ability to support effective face-to-face communication when students use the devices in the classroom. In contrast to using a desktop computer with several students, with mobile devices students do not need to crowd around one computer (Crowe, 2007; Pea & Maldonado, 2006; Roschelle & Pea, 2002). In many empirical research studies and pilot tests, participants owned the handheld devices (even though it was temporary), and such ownership involved them more in the learning process. Above all, researchers and practitioners alike have pointed out the advantages of the lower cost of these devices (Crowe, 2007; Pea & Maldonado, 2006; Roschelle & Pea, 2002; Shin, Norris, & Soloway, 2007).

Limitations and Considerations

Every technology has some limitations and weaknesses, and mobile devices are no exception. They have shown some usability problems. Kukulska-Hulme (2007) summarized these problems as follows:

> 1) physical attributes of mobile devices, such as small screen size, heavy weight, inadequate memory, and short battery life; (2) content and software application limitations, including a lack of built-in functions, the difficulty of adding applications, challenges in learning how to work with a mobile device, and differences between applications and circumstances of use; (3) network speed and reliability; and (4) physical environment issues such as problems with using the device outdoors,

> excessive screen brightness, concerns about personal security, possible radiation exposure from devices using radio frequencies, the need for rain covers in rainy or humid conditions, and so on.

It is important to consider these issues when using mobile devices and designing the learning environment.

However, looking at how rapidly new mobile products are improving, with advanced functions and numerous applications and accessories available these days, the technical limitations of mobile devices may be a temporary concern. Also, the use of mobile technologies in education is moving from small-scale and short-term trials or pilots into sustained and blended development projects (Traxler, 2007).

The most serious issue faced by mobile learning is the lack of a solid theoretical framework which can guide effective instructional design and evaluate the quality of programs that rely significantly on mobile technologies. As Traxler (2007) pointed out, evaluation of mobile learning is problematic because of its "noise" characteristic with "personal, contextual, and situated" attributes (p. 10). Several attempts to conceptualize mobile learning have been made since the emergence of mobile and wireless technologies. Traxler (2007) provided six categories by reviewing existing trials and pilot case studies in the public domain: 1) technology-driven mobile learning, 2) miniature but portable e-learning, 3) connected classroom learning, 4) informal, personalized, situated mobile learning, 5) mobile training/performance support, and 6) remote/rural/development mobile learning.

Koole (2009) developed a framework for the rational analysis of mobile education (FRAME) model which presents three aspects of mobile learning: the device, the learner, and the social environment. This model also highlights the intersections of each aspect (device usability, social technology, and interaction learning) and the primary intersection of the three aspects (mobile learning process) in a Venn diagram. What makes this FRAME model useful are the criteria and examples of each aspect and interaction and the checklist that might help educators plan and design mobile learning environments.

The definitions, technological attributes, and existing frameworks of mobile learning introduced above can help readers gain an understanding of mobile learning and how it is relevant to the future of teaching and learning with mobile technologies. However, previous studies and efforts suffer from the lack of a pedagogical framework. A number of the applications of mobile technologies in learning have shown a few links to established pedagogical theory. There is a need for the many different directions and unique applications to be logically categorized within the context of distance education. In order to better understand the current status of mobile learning and come up with comprehensive design guidelines for its future use, it is necessary to categorize educational applications with mobile technologies and position them in a logical framework. The transactional distance theory provides a useful framework based on sound

theoretical and pedagogical foundations that can define the role of mobile learning in the context of distance education.

Transactional Distance Theory

Transactional distance theory is an educational theory that defines the critical concepts of distance learning. It presents a definition of distance education which implies the separation of teachers and learners (Moore, 2007). Since its first appearance in publications (Moore, 1972, 1973), this theory has influenced numerous researchers and practices. Many scholars praise it as a classical and all-encompassing theory of distance learning (Gokool-Ramdoo, 2008; Saba, 2005) and view it as a major contribution to the field of distance education.

Transactional distance theory is defined by the fact that distance is considered not only as geographic separation but also (and more importantly) as a pedagogical concept (Moore, 1997). As a result, the theory enables the inclusion of both types of education, that is, "a program in which the sole or principal form of communication is through technology" and where "technology-mediated communication is ancillary to the classroom" (Moore 2007, p. 91). This is especially important for mobile learning because mobile devices sometimes enter the school setting (Tatar, Roschelle, Vabey, & Pennuel, September, 2003) as an ancillary element but mostly they extend beyond the classroom to non-traditional, informal, and non-institutional settings. The inclusive nature of transactional distance theory and its applicability and flexibility illustrates its important contribution to the framework for mobile learning.

This theory was derived from the concept of "trans-action," which is considered by many scholars to be the most evolved level of inquiry, compared to self-action and inter-action (Dewey & Bentley, 1946), and "the interplay among the environment, the individuals and the patterns of behaviors in a situation" (Boyd & Apps, 1980, p. 5). Thus *transactional distance* is defined as the "interplay of teachers and learners in environments that have the special characteristics of their being spatially separate from one another" (Moore 2007, p. 91). In short, transactional distance is the extent of *psychological* separation between the learner and the instructor (Moore, 2007; Shearer, 2007).

The transactional distance is controlled and managed by three interrelated factors: (1) the program's structure; (2) the dialogue that the teacher and learners exchange; and (3) the learners' autonomy. Moore (2007) explained that these three factors were derived from the analysis of (1) *curricula* of the distance learning program; (2) *communication* between teachers and learners; and (3) *the role of learners* in deciding what, how, and how much to learn. Table 1 summarizes the three elements along with the unit of analysis, focus, related questions, constructs, and degrees or ranges. However, the most appealing component of Moore's transactional distance theory is the *inverse* relationship between structure and dialogue. That is, as structure increases, transactional distance increases. However, as dialogue increases, transactional distance decreases. This hypothesis has been verified in several studies (Saba, 1988; Saba & Shearer, 1994). The theory becomes more complex by adding the third variable, learner autonomy, because it is unclear whether this represents the learner's personal autonomy or the autonomy associated with learning

materials. However, the theory explains that as transactional distance increases, so does learner autonomy.

Moore (1997) illustrated four types based on the presence or absence of dialogue (D) and structure (S), ranging from –D–S, –D+S, +D+S, to +D–S. Considering the combinations of variables that are relative and continuous rather than absolute or dichotomous, there could well be infinite types of learning and teaching. Further, for each type, learner autonomy can vary widely from complete autonomy (AAA) to no freedom (NNN), even though the right balance is necessary for successful results.

Table 1

The Three Elements of Original Transactional Distance Theory

	Structure	**Dialogue**	**Learner autonomy**
Unit of analysis	Curricula of distance learning program.[1]	Communication between instructor and learner. [1]	Learner's role. [1]
Definition	A measure of an educational program's responsiveness to learners' individual needs or preferences.[3]	Exchanges of words and other symbols between instructor and learner occurred after a course is designed, for improved understanding and knowledge construction. [1,3]	Learners' degree of freedom and self-management ability in regard to determination of learning goal, process, and evaluation.[1]
Focus	Rigidity and flexibility of structure.[1]	Extent and nature of dialogue.[1]	Dimensions and ranges of autonomy. [1]
Related question	How rigid or flexible is the distance learning program?	How many types and what quality of communication do the instructor and students generate?	How much and what kind of autonomy does the program give to learners?
Constructs	Sequence, contents, theme, objectives, outcomes, teaching and assessment strategy[2]	· Direct, indirect, active, and passive speech[3] · Academic, collaborative, and interpersonal interaction[5]	Goals, execution, and evaluation
Degrees or ranges	*Sequence:* from tightly controlled to loosely controlled *Contents:* from predetermined to postdetermined *Strategy:* from rigidly set to flexibly changeable	*Quantity:* from frequent communication to rare communication between instructor and learner *Quality:* · from deep to superficial interaction · from factual (information share) to reflective dialogue (knowledge share)[6]	From AAA to NNN[1,2] *AAA:* full autonomy *AAN:* autonomy in setting goals and execution *(external certification program)* *ANA*: autonomy in setting goals and evaluation *(programmed learning)* *ANN*: autonomy only in setting goals *(uncommon)* *NAA*: autonomy in execution
	From high transactional distance to low transactional		

	Structure	Dialogue	Learner autonomy
	distance[2] *(Examples)* – D–S: low dialogue and low structure *(e.g., textbook)* –D+S or +S–D: low dialogue and high structure *(e.g., radio program, programmed text)* +D+S or +D+S: high dialogue and high structure *(e.g., correspondence, computer-assisted instruction)* +D–S: high dialogue and low structure *(e.g., tutorial, teleconference)*		and evaluation *(uncommon)* *NNA*: autonomy only in evaluation *(most rare)* *NAN*: autonomy only in execution (*the most common situation)* *NNN*: no autonomy
Relation with TD	As structure increases, transactional distance increases.[1]	As dialogue increases, transactional distance decreases.[1]	As transactional distance increases, learner autonomy increases.[1]

Notes: [1]Moore (2007), [2]Moore (1997), [3]Saba and Shearer (1994), [4]Shearer (2007), [5]Jung (2001), [6]Sahin (2008).

Another interesting aspect of this theory is the influence of communication media on transactional distance. Using Moore's examples (2007), a recorded television or radio program is considered to have a high degree of structure because the program would not be changed to meet individual learners' needs, resulting in relatively high transactional distance; whereas an audio or video teleconference between an instructor and a single student would involve a high degree of dialogue because the instructor can change the program's structure based on individual learners' responses, resulting in relatively low transactional distance. Considering the attributes of today's advanced mobile technologies that support both individualized application and networked communication, synchronous and asynchronous communication, and text-based communication and videoconferencing, the transactional distance is influenced not only by a single communication medium but also by *diverse learning contexts*, including multiple communication methods and channels.

Benson and Samarawickrema (2009) positioned those different e-learning contexts in a two-by-two matrix of dialogue and structure and demonstrated the relative levels of dialogue, structure, and autonomy. They introduced several cases, including 1) on-campus, classroom-enhanced (-D-S-A); 2) on-campus, blended (-D+S-A); 3) workplace-based, blended (+D-S+A); 4) on-campus, multiple campuses, wholly online (+D-S+A); 5) off-campus, transactional, wholly online (+D+S-A); and 6) off-campus, transactional, partially online (+D+S+A). Although the cases were derived from two university situations, the matrix presents the categorized types of current e-learning contexts. This study points out that "transactional distance is likely to be high for students who are less familiar with learning in Web 2.0 environments" (Benson & Samarawickrema, 2009, p. 17). As a result, "teachers need to design for high levels of dialogue and structure surrounding the Web 2.0 environment in order to support students." (p. 17). This study concludes that the understanding of transactional distance theory is still useful and important for analyzing and designing such diverse contexts of e-learning.

Kang and Gyorke (2008) also state that the recent developments of social software and communication technologies require a more "seamlessly synchronized" theory (p. 203). They

compare transactional distance (TD) theory with cultural-historical activity theory (CHAT), which provides important insights about the social aspects of human activity. They point out that both theories identify "mediation" but each explains it differently. In TD theory, the physical *device* mediates communication to overcome the separation of teacher and student. In CHAT, *artifacts* including language, technology, tools, and signs mediate all of the social aspects of human activity. As a result, "in contrast to CHAT's view of communal individual, TD isolates learners from their multi-society contexts" (p. 212). This study concludes that the major variables in TD theory are "contradictory and complementary" (Kang & Gyorke, 2008, p. 211). Such a perspective is consistent with previous critiques: the variables' tautology is such that "as understanding increases, misunderstanding decreases" (Gorsky & Caspi, 2005, p. 8), but inconsistent use of terms and ambiguous relations among variables allow different people to interpret the theory differently (Garrison, 2000).

The majority of interpretations of and previous studies about transactional distance theory commonly indicate its usefulness in understanding distance learning and evaluate its usefulness as a pedagogical and philosophical framework. However, several issues raised from previous studies include 1) problems with terminology, 2) divergent views about relations between variables, and 3) an inability to explain the individual's social characteristics; thus several researchers have addressed the need for a more refined theory that addresses these issues.

A Pedagogical Framework of Mobile Learning

In this paper I do not propose a newer version of the theory but attempt to adapt it in order to review a variety of educational applications of mobile technologies and categorize them into several types to gain a better understanding of current mobile learning. While this paper follows the original concepts, I wish to make my own perspective of this theory clear and consistent.

Many researchers have interpreted TD theory in different ways and the various interpretations and operational definitions have influenced its evolution. Garrison (2000) pointed out earlier that "understanding transactional distance very much depends upon whether we are discussing a two-by-two matrix, a single continuum, or distinct clusters" (p. 9). For this paper, I choose to regard transactional distance as a single continuum from high transactional distance to low transactional distance because viewing it as a two-by-two matrix or distinct clusters makes the model more confusing due to the complex interrelations of variables. Three variables (structure, dialogue, and autonomy) control transactional distance (Moore, 1997, 2007), but as other scholars (Garrison, 2000; Gorsky & Caspi, 2005; Saba & Shearer, 1994) have pointed out, the interrelationships are inverse or orthogonal between structure and dialogue and overlapping or hierarchical between structure and autonomy (Gorsky & Caspi, 2005).

Such viewpoints about variable interrelationships in TD theory might be valid. However, in this case complex variables and their relationships with each other determine transactional distance. What we need to determine is how to define transactional distance as a single continuum. For the purpose of this paper, I adhere to the original and official definition of the theory: "a

psychological and communications space to be crossed, a space of potential misunderstanding between the inputs of instructor and those of the learner" (Moore, 1997, p. 22).

Nevertheless, when the transactional distance is defined as a psychological gap between instructor and learner, it still contradicts definitions of structure and dialogue. Due to the recent developments of emerging communication technologies, structures of learning are built not only by the instructor or instructional designer but also by collective learners; and dialogue is also formed not only between the instructor and learners, but also among the learners themselves. Working in wikis is an example of how learners build structure through dialogue (Benson & Samarawickrema, 2009). Regarding dual types of dialogue, Moore (1997) already mentioned that a new form of dialogue called "inter-learner dialogue" can make knowledge creation possible for distance learners. Structure and dialogue, previously defined as being under the instructor's control, have evolved into something that learners can also form. Because of this, every definition regarding transactional distance must now include the interaction among learners, which contradicts the original definition of transactional distance as a communicational gap between instructor and learner. To resolve this contradiction, it is necessary to define the dialogue and structure that influence transactional distance as only the interactions that take place between the instructor and learners and to exclude the interactions among learners. Any kind of dialogue and structure built by learners alone should be discussed in a different dimension. Such a dimension is discussed below.

This new dimension connotes "individual versus collective (or social)" activities by considering the importance of the social aspects of learning as well as newer forms of social technologies. This idea was formed by the influence of cultural-historical activity theory that Kang and Gyorke (2008) compared with transactional distance theory. However, I move beyond comparing each theory and synthesize them to understand some phenomena more effectively. A number of researchers (Frohberg, Goth, & Schwabe, 2009; Sharples, Taylor, & Vavoula, 2007; Taylor, Sharples, O'Malley, Vavoula, & Waycott, 2006; Uden, 2007; Zurita & Nussbaum, 2007) have utilized activity theory as a theoretical framework for mobile learning.

Some researchers recognize activity theory as a powerful framework for designing constructivist learning environments and student-centered learning environments (Jonassen, 2000; Jonassen & Rohrer-Murphy, 1999). However, certain limitations and unsolved problems in activity theory have been raised. Barab, Evans, and Baek (1996) pointed out that "life tends not to compartmentalize itself or act in ways that are always wholly consistent with our theoretical assumptions" (p. 209). They suggested researchers move from isolated to complementary theoretical perspectives. Although I do not describe the details of activity theory in this paper (Engeström, 1987; Leont'ev, 1978; Vygotsky, 1978), I do use several elements of it to modify transactional distance theory, adding a dimension and creating a pedagogical framework for mobile learning that is illustrated in Figure 3.

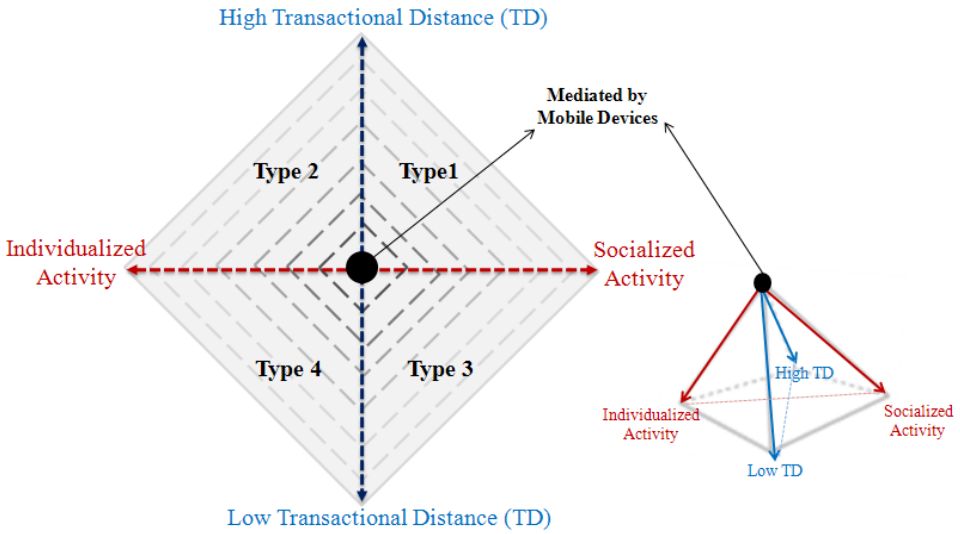

Figure 3. Four types of mobile learning: A pedagogical framework.

First, *activity* is conceived as a unit of analysis. Since transactional distance theory considers a course or program to include several lessons (Moore, 2007), this made it difficult to decide the transactional distance for the course as a whole. For example, the presentation of information is likely highly structured, while questions for discussion require high dialogue process, but both of these activities are typically course components. As a result, a course including several activities with different degrees of transactional distance cannot simply be categorized as either high or low transactional distance. Thus, by confining the unit of analysis to "activity," it is easier to determine to what extent transactional distance can exist because the activity is a "minimal meaningful context for individual actions" (Kuutti, 1996, p. 26).

Second, individualized and socialized activities are *mediated* by communication technology which is one kind of cultural-historical artifact in activity theory. As Kang and Gyorke (2008) point out, both transactional distance theory and activity theory consider mediation to be important. Thus, with "mediation" at the center of the framework, individualized activity at one extreme indicates a form where a learner is isolated from communicating with other students, and socialized activity at the other extreme indicates a form where students work together, share their ideas, and construct knowledge. At the same time, activities are mediated by the rule which can be either highly structured with fewer dialogic negotiations (high transactional distance) or loosely structured with more free dialogic negotiations (low transactional distance). As mentioned above, mobile learning is "mediated learning by mobile technologies" (Winters, 2006) and the mobile technologies uniquely support students' learning both collectively and individually (Koole, 2009). In placing high or low transactional distance on the *y* axis and individualized or socialized activity on the *x* axis, the framework generates four types of mobile learning activities.

Third, the dualism of *individual* versus *collective* (or social) is a dichotomy, but it is also something to be connected and balanced. Activity theory has attempted to transcend the issue of dualism in such pairs as individual-society, subjectivity-objectivity, agency-structure, psychological-social (Roth & Lee, 2007; Watson & Coulter, 2008). However, according to

Garrison (2001), Leont'ev's activity theory (1978) drew close to Dewey's theory of transactional coordination, but Dewey pushed his functionalism beyond describing "inter-actions" to a theory of "trans-actions." There are similarities and differences between the approach of activity theory and the approach of transactional distance theory derived from Dewey's work. Activity theory is an analytic framework for understanding an individual's (subject) actions on learning material (objects) mediated through artifacts, interacting with a community, moderated by a set of rules, and distributed by a division of labor (Engeström, 1991). It forms a part of the basis for transactional distance theory, which is a framework for understanding the relations of key variables (structure, dialogue, and autonomy) in the context of distance learning. Although a number of important concepts from activity theory are simplified in Figure 3, a dimension indicating the range of individualized to socialized activity can be a useful lens for reviewing diverse mobile learning activities. Above all, the distinction between individual and socialized activity is a generally understood and accepted categorization; for example, Keegan (2002) stated that distance learning has two forms, individual and group learning.

Educational Applications of Mobile Technologies

The major purpose of this study is to review and classify a variety of educational applications with mobile technologies. For this purpose, a conceptual and pedagogical framework was generated based on high versus low transactional distance and individualized versus socialized activity. As shown in Figure 3, the four types of mobile learning generated in the context of distance education include (1) high transactional distance socialized m-learning, (2) high transactional distance individualized m-learning, (3) low transactional distance socialized m-learning, and (4) low transactional distance individualized m-learning.

Type 1: High Transactional Distance and Socialized Mobile Learning Activity (HS)

A mobile learning activity is classified as this type when 1) the learners have more psychological and communication space with their instructor or institutional support; 2) the learners are involved in group learning or projects where they communicate, negotiate, and collaborate with each other; 3) learning materials or the rules of activity are delivered from the predetermined program through mobile devices; and 4) transactions mainly occur among learners, and the instructor or teacher has minimal involvement in facilitating the group activity. This type might replace the traditional technology-mediated classroom group activity where students in a group or pair conduct given tasks or assignments.

NetCalc (Vahey, Roschelle, & Tatar, 2007; Vahey, Tatar, & Roschelle, 2004), for instance, is a handheld version of SimCalc, an application designed to help middle school students learn mathematics of change and variation. Three innovations were considered during the development of the SimCalc project, "restructuring the subject matter, grounding mathematical experience in students' existing understanding, and providing dynamic representations" (Vahey, et al., 2004, p. 554). NetCalc allowed students to play games in pairs and practice very specific mathematical

concepts. For example, in the game Match-My-Graph "one student (the grapher) creates a function that is hidden from the other (the matcher). . . . The matcher makes and beams an initial guess of the function, and receives a verbal clue from the grapher" (Vahey, et al., 2004, p. 555). While this game involves learning the characteristics of position graphs and velocity graphs and how to translate between each kind, the mobile activity supported both "communication capabilities and representational infrastructures of handheld computers" (p. 553).

The MCSCL system (Cortez, Nussbaum, Santelices, Rodriguez, & Zurita, 2004) is another example of this type. This system was developed to teach high school students in a physics classroom. It was designed and implemented for students in groups to answer a set of multiple-choice questions transmitted through mobile devices. In this activity, students have to debate how to answer the questions and must come to an agreement on the choices that the group selects. In this process, they modify their existing knowledge schemes and construct new knowledge by collaborating with other students. The teacher helps to set up and transmit the questions to students prior to the collaborative activity and collects the students' work afterwards.

The Math MCSCL project (Zurita & Nussbaum, 2007) utilizes activity theory as a conceptual framework; an activity was developed to enable Grade 2 students to practice addition, subtraction, and multiplication in a group. In this activity, students with a certain number of objects (such as bananas, apples, and oranges) on their mobile device have to reach the target quantity for each object by exchanging them with other students. Individual students keep track of the quantities of each object by performing arithmetic operations and search for other students who can exchange objects with them. They have to talk, negotiate, and collaborate to achieve the goal of the game.

The examples introduced above were selected as high transactional distance because these activities all require a highly structured program. Questions for activities or the rules of the game are determined prior to the activity. Although the content area in the above examples was science or mathematics, these activities nonetheless required and aimed to build social interaction, negotiation, and collaboration skills among group members. In developing this type of activity, instructors and instructional designers may need to give special attention and effort to 1) the design of the mobile application and 2) the setup of social interaction, such as defining the rules of the game and the roles of players. Considerations on both the computational (software) aspect and the functionality (hardware) aspect of mobile devices might be critical to successful implementation of the activity.

Type 2: High Transactional Distance and Individualized Mobile Learning Activity (HI)

Mobile learning activities are classified as type 2 when 1) the individual learners have more psychological and communication space with the instructor or instructional support; 2) the individual learners receive tightly structured and well organized content and resources (e.g., recorded lectures, readings) through mobile devices; 3) the individual learners receive the content and control their learning process in order to master it; and 4) the interactions mainly occur

between the individual learner and the content. This type demonstrates an extension of e-learning which allows greater flexibility and portability. Individual learners fit this flexible learning into their mobile lifestyle. This type is mostly influenced by the context regarding when and where to learn. It also includes mobile learning that makes access to the educational system possible for students in rural areas.

The off-campus postgraduate development program of the Australian National University (Beckmann, 2010), is an example of this type, implemented both online and on mobile modes of distance learning. For the MAAPD (Master of Applied Anthropology and Participatory Development) program, students who are enrolled in distance learning are offered downloadable resources (e.g., readings, audio or video lectures, presentation slideshows, etc.) and opportunities to interact with others in online discussion. The major role of lecturers is to establish the online discussion and upload podcasts and vodcasts to the learning management system (LMS). Authoring tools such as Camtasia studio or Wimba Create were utilized to build these media-rich resources. Although learning activities and tasks based on a constructivist perspective were implemented and demonstrated, comments on this project describe the benefits of mobility. The responses of participants included these statements: “the ability to download lectures onto my iPod while I was travelling was really useful” (p. 166), and “I downloaded lectures (audio version) . . . played them over my stereo via my laptop while I cooked dinner at home . . . this was invaluable as I had a very demanding job” (Beckmann, 2010, p. 169). This feedback shows that mobile devices are utilized to make it possible for individual workers with busy schedules to learn at their preferred places and times.

Mobile learning for students in remote sites or underserved areas is another typical example of this type. Vyas, Albright, Walker, Zachariah, and Lee (2010) applied mobile technology to clinical training at remote secondary hospital sites in India. Synergy was achieved with the use of the TUSK knowledge database through the partnership of the Christian Medical College (CMC) in India and Tufts University School of Medicine in the US. This is a mobile learning system that is part of campus-based e-learning supports in CMC. It is designed to enable students to access a knowledge repository through their own mobile phones and to fulfill their learning needs using other mobile applications.

As another example, Kim (2009) shared action research to design a mobile learning project for underserved migrant indigenous children in Latin America. In this project, mobile learning was utilized to develop the literacy of migrant children who live in villages far away from the centers of towns, where a formal education is not easily accessible. Through early prototypes of mobile devices, an *Alfabeto* lesson is delivered to children. The lesson displays alphabet letters and sample words starting with each letter, delivers a voice recording of letters and words, and provides short stories with sequenced animations and corresponding texts. This project shows how the portability and multimedia features of mobile technology as well as its low cost can help disadvantaged populations, including illiterate children and their families who live far away from public services such as education or health care.

Mobile assisted language learning (MALL) is a notable example of type 2. MALL is distinguished from computer assisted language learning (CALL) because it focuses on the "continuity or spontaneity of access and interaction across different contexts of use" (Kukulska-Hulme, 2009, p. 162). As an example of such a function of "context-awareness" Chen and Li (2010) applied a wireless positioning technique to a program for teaching English vocabulary. Individual learners discover and learn new vocabulary by logging in to a personalized context-aware ubiquitous learning system (PCULS). The system retrieves learners' personal portfolios, including their leisure time and English level, automatically senses their location, and appropriate vocabulary material is suggested from the database based on the learner's portfolio and location context. In spite of technical problems (e.g., access difficulties), there is a relatively high success rate in detecting the learner's location and facilitating enhanced learning performance. Learner satisfaction in the experiment holds promise for a future seamless ubiquitous English learning environment.

Although it was not possible to find a case in the scholarly literature in which the learners simply accessed open resources (e.g., YouTube) or online tutorials through mobile devices, such a case could also fall into this type because individual learners engage in self-directed learning as they search for information and gain knowledge without the intervention of a teacher or instructor. The examples introduced above represent relatively high TD because the instructor or teacher played a minimal role in helping individual learners take control of the learning process. Individual learners in this type decided where and when to learn and personalized their learning environments. In developing this type of mobile learning activity, instructional designers or institutional distance learning support staff should pay special attention to the creation and management of a knowledge database, including well-organized learning materials such as lecture (audio or video) files, reading materials, and vocabulary databases. The most important considerations might be accessibility and technical connection problems. The studies introduced above commonly indicated such technical issues caused by different learner environments.

Type 3: Low Transactional Distance and Socialized Mobile Learning Activity (LS)

In this type, individual learners interact both with the instructor and other learners as they use mobile devices. They have 1) less psychological and communication space with the instructor; and 2) loosely structured instruction; but (3) work together in a group as they solve the given problem and try to achieve a common goal; and (4) engage in social interaction, negotiation, and frequent communication naturally. This type demonstrates the most advanced forms in terms of the versatility of mobile devices and learners' social interactions.

Klopfer, Squire, and Jenkins (2002) developed and Klopfer and Squire (2008) examined *Environmental Detectives*, a simulation platform designed as a game for mobile devices. Students play the role of environmental engineers and are given a scenario in which the spread of a toxin is simulated on a location-aware Pocket PC equipped with a GPS (geographical positioning system). The Pocket PC allowed students to investigate a toxic spill by collecting samples to test for chemicals in the groundwater and required them to respond to different

variables programmed by the teacher. Many students indicated that these types of collaborative activities helped them evaluate diverse choices, motivated them, and transformed their perceptions of learning.

An audio-based learning forum project (Chang, 2010) enabled learners to participate in an asynchronous learning forum on mobile devices, which replaced the text-based discussion online forum. Since multimedia message services (MMS), an evolved form of short message services (SMS), can send not only text but also graphics, video, and audio clips, this project utilized audio-based input to post discussion articles in an audio file format. Learners can download audio files recorded by their peer learners and listen while on the move. Although there are some disadvantages, such as background noise, the inability to search through a message, and difficulty in reviewing the recorded audio files, hands-free operation and the flexibility of learning are great advantages. In order to increase the participation in discussion and collaborative learning, a team game tournament (TGT) was integrated into this activity. Heterogeneous groups consisting of three members were initially formed then regrouped for the tournament based on their performance in the first round.

Relatively few studies of this type exist. A common characteristic in both examples is that concrete contents or a specific learning outcome are not defined prior to starting the activity. Also, mobile devices are utilized for multiple functions as an investigation tool, a communication tool, and a simulation and game tool. When developing this type of learning, instructional designers and instructors should promote active participation and allow students to have many social experiences. The most important consideration is to develop a meaningful collaborative task or a complex situation so that higher order thinking, negotiation, evaluation, reflection, debate, competition, and scaffolding can naturally occur.

Type 4: Low Transactional Distance and Individualized Mobile Learning Activity (LI)

This last type of mobile activity refers to 1) less psychological and communication space between instructor and learner and 2) loosely structured and undefined learning content. On this basis, 3) individual learners can interact directly with the instructor, and 4) the instructor leads and controls the learning in an effort to meet individual learners' needs while maintaining their independence. This type shows characteristics unique to mobile learning that support blended or hybrid learning.

A large blended classroom project in China (Shen, Wang, Gao, Novak, & Tang, 2009; Wang, Shen, Novak, & Pan, 2009) is a similar approach to type 2 as it pursues anytime, anywhere learning. However, this project aims to increase Chinese students' class interactivity using technical intervention. In the upper-level English class, a mobile phone broadcasting system, classroom management system, and a networking system are all established for distance learners not only to download course materials but also to connect with the class in real time, while the instructor provides lectures using a computer, a projector, whiteboards and other tools for instruction. Since this type of learning is a kind of large-scale lecture, frequent dialogue between

instructor and students is difficult (that is why it is not categorized as type 2, high transactional distance). However, students can send messages and ask questions of the instructor using their mobile phones, and the instructor can respond to them with an oral explanation in real time. This function, enabled by mobile technology, supports a reduction of transactional distance.

Mobile butterfly-watching and bird-watching learning system (BWL) projects (Y.-S. Chen, Kao, & Sheu, 2003; Y.-S. Chen, Kao, Yu, & Sheu, 2004) support outdoor mobile learning activities. In these projects, mobile devices were used by independent learners to access a bird or butterfly knowledge database to match the butterfly or bird that they observe and photograph. In this system, mobile devices make field trips for science learning much simpler because learners do not need to carry a notebook for observation and can find the necessary information more easily and quickly. They take pictures with the digital camera that is built into the mobile device, store their notes in it, and send them to the server using a wireless internet connection. While the teacher encourages students to observe diverse objects and assigns questions to make sure they are learning, students engage mostly in self-directed and independent learning, and the mobile devices support the learning process through scaffolding.

Because a teacher mainly controls and leads the activities in this type, and learning contents and processes are structured as individual students reach the end of the activity and the class, these examples are considered low transactional distance. Also the flexibility and portability afforded by the mobile devices supports individualized learning. To prepare for this type of learning, instructional designers and teachers should pay attention to the student environment from a distance both in the classroom and on field trips and should provide appropriate supports as students ask questions and complete the given tasks or assignments.

Conclusion

In this paper I introduced a definition of mobile learning, outlined its characteristics, and compared it with e-learning. Despite the great potential mobile learning has and the innovative development of mobile technologies, a theoretical framework in which to review diverse mobile learning projects in the context of distance learning has been lacking. The framework for this analysis was adopted from transactional distance theory and modified by adding a new dimension to reflect the characteristics of mobile technologies that support both individual and social aspects of learning. Previous studies dealing with mobile learning were reviewed and categorized into four types based on transactional distance and individualized versus socialized learning.

The literature reviewed in this study was limited to a few examples from the rapidly growing body of research on mobile learning. Although a small number of case studies have been introduced here, there are several other exemplary projects which can be classified within the four types of mobile learning activities. I developed this classification scheme hoping to help instructional designers and instructors to design and implement mobile learning more effectively. Reviewing mobile projects within the framework of the four types also confirmed that mobile devices uniquely support seamless movement and switch (Looi et al., 2008; Vahey, et al., 2007)

between individualized (personalized) and socialized learning and between high transactional distance and low transactional distance.

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