Identifying learning features and models for context-aware ubiquitous learning with phenomenological research method

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Abstract: Context-aware ubiquitous learning (u-learning) is an emerging paradigm of e-learning, and it provides new educational practices for knowledge and skill development. This paper focuses on the identification and analysis of u-learning effectiveness to develop a learning design model to guide interested practitioners via phenomenological research method. The authors first examined 21 identified u-learning studies cited at least five times in the Web.

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of Science to conduct the first step of phenomenological research method, bracketing the phenomenon. Later, the researchers followed the needed procedure of the phenomenological research method, including collecting interview data, identifying meaningful statements, giving meanings to those statements, and creating rich descriptions. The results demonstrate possible features of u-learning and the learning design model based the features to increase the learning effectiveness, and interested practitioners can apply the proposed learning design model proposed after the identification of learning effectiveness of the selected u-learning studies when constructing u-learning projects.

Keywords: qualitative analysis; human–computer interaction; instructional technology; ubiquitous learning; context awareness; phenomenological research method.

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1 Introduction

Studies of context-aware technologies should be extended to include ubiquitous computing systems and research into human–computer interaction, with the aim of better enabling these devices to foster knowledge embodiment, a concept that has been developed in phenomenology (Dourish, 2001; Enriquez, 2011). Context-aware ubiquitous learning (u-learning) refers to a new paradigm of e-learning where users interact with the environment through wireless communication and sensor technologies, receiving information from mobile devices (Hwang and Tsai, 2011; Liu et al., 2015; Liu and Hwang, 2010; Poslad, 2009). The u-learning process not only triggers users’ perceptions, but also initiates and deepens learning effectiveness (Chu et al., 2010; Shih et al., 2011). Learning effectiveness in a web-based learning environment is composed of the learning climate and learner satisfaction (Chou and Liu, 2005; Hannafin et al., 2009), including learning contexts and learner achievements.

U-learning combines sensor technologies, like Radio Frequency Identification Technology (RFID) and Quick Response codes (QR codes), with mobile devices. The sensors attached to the learning objects in authentic contexts give users the learning materials, which may be verbal or non-verbal information simultaneously (Huang et al., 2011; Liu et al., 2014b; Hwang et al., 2010; Liu and Hwang, 2010; Poslad, 2009). Currently, growing attention has been given to u-learning in both research and practices (Enriquez, 2011; Hwang and Tsai, 2011).

Appropriate learning designs are necessary to make learning more meaningful and effective. In the development of Technology-Enhanced Learning (TEL), two goals are emphasised, namely building computer systems to deliver learning resources and identifying the appropriate designs for TEL (Falconer et al., 2011). Research into TEL seeks to negotiate between instructors’ pedagogies and learner needs via a well-designed context (Enriquez, 2011; Kali et al., 2011). In addition, Dourish (2001) argued that TEL researchers take ‘phenomenology as a basis for the development of a new framework for design and evaluation of context-aware technologies’ (p.229), and ‘work on sociological investigations of the organization of interactive behavior’ (p.229). The aim of this study is thus to develop a learning design model by identifying the features of learning effectiveness in context-aware u-learning and investigating related perspectives of u-learning designers with the phenomenological research method (Moustakas, 1994; Randolph, 2009) to provide both teacher educators and researchers with a thorough theoretical consideration regarding the nature of u-learning (Graham, 2011).

2 Reviewing relevant perspectives of u-learning and bracketing the phenomena

The main characteristics of u-learning include mobility, interoperability, seamlessness, location awareness, social awareness, adaptability and pervasiveness (Yang et al., 2008), and this new learning paradigm is to offer a diverse range of learning activities for learners. To gain a deeper understanding on the nature of u-learning including the characteristics of u-learning environments and its effects on learners’ performance, this paper first reviewed the identified perspectives to have a clear picture of u-learning regarding the learning effectiveness with a specific focus on the following elements: personalised learning environments, strategy-driven learning designs, learner memory,
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learning achievement, and learning motivation. The first two items address the issue of u-learning environments and the last three perspectives deal with the outcome of u-learning practice. After extracting the identified perspectives towards u-learning, researchers bracketed their current understanding of the perspectives to probe the practical phenomenon neutrally. Viewing all these identified features as a whole, these perspectives are integrated when it comes to a construction of a design model for u-learning. However, these perspectives will be separately discussed to give a complete outline of issues related to the learning processes.

2.1 Personalised learning environments

U-learning utilises mobile devices offering a unique and personal platform for developing learner-centred educational experiences via personalised information and services (Low and O’Connell, 2006; Poslad, 2009). Learners in u-learning environments can learn from the materials provided by u-learning systems based on their own learning pace and preference (Chen and Huang, 2012; Huang and Chiu, 2015). In addition, the characteristic of combining authentic situations enhances the development of location-based services where learners can access relevant and contextual information based on their different tasks and needs. This interrelationship between the contextualisation and personalisation of learning is based on the concept of learner-centred learning, emphasising personal needs and goals, differences in knowledge and interests, as well as environmental factors (Enriquez, 2011; Poslad, 2009; Zimmermann et al., 2005).

Low and O’Connell (2006) further identified 4Rs (Record, Reinterpret, Recall, and Relate) as the building blocks for mobile activities, and these are often used in u-learning. In short, the devices can be applied to help learners gather knowledge based on their own learning paces, and the learners can then act as analysts who select and discover new information through the guidance of u-learning systems at their prefer time. In addition, learners can utilise devices to review this information, which facilitates recall, and the information then becomes part of a network of knowledge that is enmeshed in the users’ social context in the contexts of location-aware learning (Low and O’Connell, 2006).

2.2 Strategy-driven learning techniques in u-learning

Teachers employ different instructional techniques to improve students’ learning, and several instructional strategies have been found to be helpful including active learning, critical thinking, experiential learning, games, and simulations. In u-learning environment, a number of unique learning strategies are favoured including collaborative learning and task-aware supervised learning, which are briefly introduced, as follows.

Shih and Tseng (2009) stated that location-aware learning is developed based on a mobile Geographical Indication System (GIS), which represents the user’s current location and activities, and applications of location-aware learning include pedestrian navigation support or the promotion of collaborative learning.

Collaboration among learners is important, and students that work together can have better learning performance than those that operate alone (Hwang et al., 2011). Two or more people work together with u-learning devices and systems through deeply involving in the process of learning by presenting ideas, sharing experiences, discussing details, and evaluating performance. Also, collaborative learning redefines traditional teaching
and learning as a more student-centred learning environment resulting in a more interactive relationship among teachers and students (Fischer et al., 2013; Xu et al., 2015). However, successful teamwork requires team members to maintain awareness of what others are doing (Liu et al., 2008).

Task-aware supervised learning refers to learning during the process of solving problems. Some researchers argue that the environments used in u-learning have too many variables or alternatives, and this may lead to cognitive overload for learners, since they have to receive information from both the real and digital worlds simultaneously (Hwang et al., 2010; Liu, 2010; Liu et al., 2014a). To reduce this cognitive load, the task-aware supervised design of u-learning gives specified learning paths that learners can follow to arrive at the target learning object. For example, in a museum, the support of ubiquitous context-aware learning is able to identify the learning elements and associate different individuals’ knowledge of them with their usage profiles. This process uses a data-mining algorithm, which clusters data and searches for useful patterns based on personal needs. In the pre-learning stage, learners can browse the introduction of the museum and find the exhibit they are interested in, which they can then visit and carry out on-site learning (Hsu et al., 2006). Advanced learner knowledge can thus be constructed, and this personal task-aware learning reinforces learning effectiveness, as it focuses on the personal needs of individuals, thereby increasing their learning motivation.

2.3 Learner memory

Human brains process information and store it as internal knowledge, and a key concern for learning effectiveness is whether students can mentally internalise the learning materials they encounter. Working memory and long-term memory are distinctive in their functions in the learning process. Working memory is short term in nature and relates to cognitive load (Hannafin et al., 2009), and thus refers not only to what can we remember, but also to what can we comprehend in a certain period of time. The construction of long-term memory relies on meaningful input and a certain amount of practice. Comprehensive and meaningful input thus benefits learners in retrieving and recollecting material (Hannafin et al., 2009), and the design of u-learning provides an authentic context (Hwang et al., 2009; Rouillard, 2008) in which users can see the real objects and often interact with them, triggering multiple intelligences, such as spatial intelligence, which works to promote learning effectiveness. For example, research indicates that a u-learning context where users can control their learning schedule based on their cognitive load is effective for recall of contextual events and supporting memorisation (Kawamura et al., 2007). Further, some researchers combine other educational tools, like contextualised blogging with a u-learning context, to provide learners with an opportunity to annotate real-world contexts and learning content based on their personal perspectives, with the hope that the real application context enables knowledge transfer and reinforces internalised long-term memory (De Jong et al., 2007).

2.4 Learning achievement

U-learning has a number of unique features that can overcome some of the drawbacks of web-based learning, by means such as providing a concrete sequence in the authentic world with navigational support (Chiou et al., 2010; Liu and Hwang, 2010). Mobile
devices are used in u-learning, which utilises the characteristics of such technologies, such as greater permanency, accessibility, immediacy, interactivity, calmness, adaptability, seamlessness and immersion (Liu et al., 2009). In addition, the situational context is a feature of u-learning, as the system can detect the position of learners via the sensor network and send them authentic information related to this. The integration of u-learning in teaching plans can increase learning achievements by offering greater immersion and providing more learning experiences, which can enhance learner comprehension to a greater extent than with drill-based approaches (Paiva et al., 2016).

Integrating u-learning into curricula has been employed in many fields (see Table 1), and a number of studies (e.g. Chu et al., 2010; Chiou et al., 2010; Liu and Chu, 2010) have found that learning achievement is indeed promoted with higher levels of immersive learning. Interaction plays a crucial role in language learning, and to enhance the frequency of interaction, especially in the training of listening and speaking, some researchers add ubiquitous games and augmented reality (AR) environments into their u-learning designs. The results show that learners using such applications have better learning performance than others with regard to the outcomes of attention, relevance, confidence, and satisfaction tests (Liu and Chu, 2010). To extend or apply knowledge learned in school, researchers have developed museum learning systems with u-learning activities and applications, and have overcome the limitations of this technology, such as a large number of people visiting the same learning object, by giving users personal learning paths. This kind of approach gives learners a high level of control over the content of their learning, and this has been shown to be both efficient and effective in enhancing learning achievement (Chiou et al., 2010).

Table 1 Learning achievement in different u-learning applications

<table>
<thead>
<tr>
<th>Application type</th>
<th>Learning achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning with ubiquitous games</td>
<td>Improving English listening and speaking (Liu and Chu, 2010; Liu et al., 2015)</td>
</tr>
<tr>
<td>Conducting complex science experiments</td>
<td>Achieving more systemic and economic learning (Hwang et al., 2009; Sung et al., 2014)</td>
</tr>
<tr>
<td>Learning in museums</td>
<td>Utilising the learning resources more efficiently (Chiou et al., 2010; Wang et al., 2016)</td>
</tr>
<tr>
<td>Learning natural science outdoors</td>
<td>Promoting creativity (Liu et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Improving learners’ ability to explore new knowledge (Hung et al., 2014; Tan et al., 2007)</td>
</tr>
</tbody>
</table>

With u-learning, teachers and students can obtain resources and interact easily when outside the classroom, and the learning records management mechanisms in such systems can store learning profiles and allow teachers to give instant feedback to their students, significantly improving their learning achievement (Tan et al., 2007). However, some research indicates that the positive effects of u-learning may be based to a large degree on the excitement and novelty that users feel when using the related gadgets, and that once they are more familiar with the technology then this higher level of learning achievement might disappear (Chu et al., 2010). Therefore, it is important to use a systematic learning scenario and give timely, helpful feedback to learners, so that their learning motivation can further be maintained and they will continue to undertake autonomous learning.
2.5 Learning motivation

U-learning, like other types of e-learning, usually combines collaborative learning in the course design, and the mobile devices used can give relevant hyperlinks to learners, create more learning opportunities, and lead to more efficient learning. The following features of u-learning all enhance the likelihood that students will have increased and prolonged learning motivation:

- The novel learning devices, like smartphones, attract learner attention (Liu and Chu, 2010).
- The hyperlinks give more relevant resources to users, who want to know more about a specific topic (Liu et al., 2009).
- The varied resources offered promote learner creativity (Liu et al., 2009).
- The combination of collaborative learning enhances learning efficiency (Chen and Chao, 2008).

The gadgets used in u-learning can be used to edit documents, view websites, take photos, and make phone calls. Some researchers install games related to English learning (Liu and Chu, 2010) on such devices, and the results show these new stimuli can significantly increase learning motivation. In addition, the ability to go online means that learners can use smartphones to search for more information about things they are interested in or resources they need, and this kind of adaptive learning also raises learning effectiveness and increases learning motivation (Pandey et al., 2013). In outdoor u-learning design contexts, learners who utilise hyperlinks demonstrate higher levels of creativity, and they are more capable of exploring and absorbing new information, as well as solving problems (Liu et al., 2009). In addition, a collaborative learning design is usually integrated into the u-learning context, where individual geographical and learning situations are detected, and context-aware learning support is then provided. With traditional book-based learning, learners are not able to get immediate feedback, and if they want to engage in discussions with their peers they must gather in the same place at the same time. U-learning devices make it much more convenient to conduct collaborative learning courses, in which learners construct their knowledge by synthesising the different perspectives of their peers (Chen and Chao, 2008), and consequently their learning motivation can increase based on the stimulus of others’ contributions and learning reflections.

2.6 Key features of u-learning design

A learning design model is composed of designers’ knowledge, experience, and practice, and is the skeleton of learning activities. In the educational technology field, the features of the used technologies will change the design of the learning activities that go with them (Van Diggelen and Overdijk, 2009). In terms of the characteristics of context-aware ubiquitous learning, the immediacy, interactivity, and permanency of the related technologies (Chiou et al., 2010; Liu and Chu, 2010; Tan et al., 2007) thus change the direction of learning models that are designed. In the following, the interrelationship between the characteristics of technologies and u-learning design was examined based on
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the empirical evidence found in the previous literature. Studies focus on the development of system models in u-learning designs. For example, Chiou et al. (2010) developed a u-learning navigation support system based on the capacity of the system, immediate responses, and dynamic configuration, and formulated the related model using a heuristic algorithm approach. The navigation support system model thus produced can provide possible solutions to users, and is appropriate for use with problem-based learning strategies. Hwang et al. (2010) further presented a butterfly learning activity based on the heuristic algorithm approach to develop their system model to provide personalised learning paths. Finally, Shih and Tseng (2009) developed a context-aware learning content retrieval system based on the ontology-driven model and the results show that it improves the learning performance of users. Moreover, based on Liu and Hwang (2010), the sources of u-learning effectiveness were divided into two categories: the external inputs through u-learning systems, and the internal learning frames from the learners’ perspectives (Liu and Hwang, 2010). The former are related to the design of soft technologies (which refers to instructional techniques, guidelines, strategies or models that foster meaningful learning) that are produced in order to make good use of hard technologies, which refers to both hardware and software (Jonassen, 2004; Liu, 2011).

To enhance learners’ control of the learning pace, sequence, and content, Liu et al. (2009) proposed an Environment of Ubiquitous Learning with Educational Resources (EULER) system for outdoor science learning activities. The system model of EULER has two sub-systems, the mobile interactive learning server and the mobile content database. Users can adjust their learning pace in the EULER system with user-friendly mobile tools and the wireless internet, be aware of their own learning sequence through the immediately accessible learning resources in the system, and acquire learning content by sharing and exchanging information with peers. In addition to designing a system model for users, Chu et al. (2010) proposed an innovative model for u-learning designers with the following procedure: deciding learning objects, enhancing the repertory grid, and developing a Mindtool for u-learning.

Other researchers emphasise the importance of pedagogical learning models in a context-aware ubiquitous environment. For example, Liu and Chu (2010) conducted a u-learning experiment for English listening and speaking learning activities, following Keller’s (1987) ARCS motivation model – based on attention, relevance, confidence, and satisfaction – to design their learning activities, and received positive feedback from learners. Enriquez (2011) examined mobile learning from the perspective of how to place users in the learning process, and emphasised the importance of user-related issues for designers, such as how users experience mobility of learning.

In order to construct knowledge more effectively and facilitate users’ long-term memory, İşman (2011) stressed the design of teaching and learning activities. He constructed an instructional design model, called the İşman model, based on active learning. The five steps included in the model are: input, process, output, feedback, and learning. He suggested that it is crucial to investigate and clarify learners’ needs and motivate them via well-designed activities. Moreover, the close connection between design and context reflects the integration of all aspects of the u-learning model (Van Diggelen and Overdijk, 2009). Most of the current studies of u-learning focus on designing system models (Chiou et al., 2010; Hwang et al., 2010; Shih and Tseng, 2009) and pedagogical models (Chu et al., 2010; Liu et al., 2009; İşman, 2011). However, few u-learning studies explore models derived from users’ actual learning processes, which
are appropriate for use by designers as a reference for use in their u-learning designs. In this study, we will produce a learning design model derived from the factors that influence users’ learning effectiveness in u-learning environments.

3 Research questions

The purpose of this study is to find out the sources of learning effectiveness in u-learning based on the u-learning designers’ understanding and experience. The following research questions were formulated to achieve this:

- RQ 1: What features can be identified in u-learning to enhance learning performance?
- RQ 2: Based on the sources of learning effectiveness identified in response to RQ 1, what is an appropriate learning design model for u-learning?

4 Methodology

The research design of this study is based on the phenomenological research method (Moustakas, 1994; Randolph, 2009), which is a qualitative way to conduct research that has the goal of arriving at the essence of the lived experience of the focal phenomenon. It includes the following five steps: bracketing the phenomenon, collecting interview data, identifying meaningful statements, giving meanings to those statements, and creating rich descriptions, as shown in Figure 1.

**Figure 1** The research design in this study based on the phenomenological research method

```
1. Bracketing the Phenomenon
   The researchers read u-learning studies to identify
   the major sources of u-learning effectiveness.

2. Collecting Interview Data
   We invited five people with experience of u-learning
   design to participate in this study.

3. Identifying Meaningful Statements
   We analyzed empirical data and highlighted the
   meaningful statements from interviews.

4. Giving Meanings to those Statements
   We sorted the statements based on
   categorical aggregation.

5. Creating Thick Descriptions
   We synthesized the data in order to develop
   categorized information and shed light on the
   contributions of various elements to u-learning
   effectiveness.

Outcome
   We summarized the main
   points and initiated a
   learning design model for u-learning.
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4.1 Procedure

4.1.1 Bracketing the phenomenon

Before the interviews were conducted, the researchers read 21 identified u-learning studies that have been cited five times or more in the Web of Science until 31 December 2012. The key words used for searching related papers included u-learning, ubiquitous learning, context-awareness, and situational learning. The reason why those articles were chosen was because those papers cited for more than five times provided both researchers and teacher educators in the field of u-learning with insights on both development and implementation of u-learning. These studies published from 2005 to 2011 were analysed to identify the major sources of u-learning effectiveness providing both researchers and teacher educators with an overall understanding on u-learning. More specifically, the learning environments are related to the design of the hard technologies, like the RFID tags and mobile learning devices, and the software designs are related to the learning strategies, like collaborative learning approaches. The internal learning frames are related to the learners’ interior learning processes, such as their learning motivation and learning achievements (Liu and Hwang, 2010). After identifying those perspectives from reviewing literatures, researchers bracketed above perspectives in this section and further remained neutral to collect data by interviews (Green, 1995).

4.1.2 Collecting interview data

In phenomenological studies, it is crucial to interview people with experience of the focal phenomenon (Randolph, 2009) as such interviews help researchers get first-hand data to explore the essence of the related issues. Therefore, in this study we conducted interviews with five practitioners who had experience of designing u-learning projects and activities and who had the willingness to participate in the interviews in order to find out how to increase learning effectiveness in such contexts. Semi-structured interviews were conducted, and each interview lasted for approximately 30 minutes. All the six interview questions centred on the major features and bracketed phenomena found in the literature at early stage of the present study, and all the questions were open-ended questions to elucidate meaningful comments. Table 2 shows the backgrounds of the five participants recruited for the interviews. The inclusion criteria were having experience of designing u-learning projects and publishing research results in academic journals.

The researchers conducted the interviews face-to-face, with all five participants interviewed separately based on the procedure proposed by Worthen and McNeill (1996). The interview questions were formulated based on the research questions, and after each participant had signed a consent form, the researchers conducted the interview and recorded it with an MP3 player.

The role of the interviewer was to ask the participants to clarify their answers to avoid ambiguity and elicit more details when needed. In the interview process, the interviewer prompted the participants with questions such as: ‘Could you give more details about your u-learning project?’, and ‘Can you recall the process of designing and testing your u-learning project?’
Table 2  The participants’ backgrounds

<table>
<thead>
<tr>
<th>Gender</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
<th>Participant 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>31</td>
<td>28</td>
<td>25</td>
<td>29</td>
<td>25</td>
</tr>
<tr>
<td>Educational level</td>
<td>PhD</td>
<td>Master’s degree</td>
<td>Master’s degree</td>
<td>PhD</td>
<td>Master’s degree</td>
</tr>
<tr>
<td>Major with a specialised field</td>
<td>U-learning &amp; m-learning</td>
<td>U-learning &amp; m-learning</td>
<td>M-learning</td>
<td>E-learning</td>
<td>E-learning</td>
</tr>
<tr>
<td>Months spent undertaking u-learning design</td>
<td>60 months</td>
<td>36 months</td>
<td>30 months</td>
<td>36 months</td>
<td>20 months</td>
</tr>
</tbody>
</table>

Note: The three topics (u-learning, m-learning, and e-learning) are defined as in Liu and Hwang (2010).

When the participants had answered all the questions and the interviewer considered that they had fully described their related experiences, the one last question was asked, as follows: ‘Do you have further suggestions or anything you would like to add in this interview?’ Most of the interviewees suggested that future u-learning projects should focus on how to construct a reusable system for different academic subjects, as this might lower the cost of designing such projects, and that the time thus saved might enable designers to focus more effort on the learning materials.

4.1.3 Identifying meaningful statements

Based on the phenomenological research method, the researchers analysed the empirical data and then used the following steps to highlight the meaningful statements in the participants’ experiences.

*Step 1: Immersion in the Data* (Patton, 2002): To understand each participants’ experience of u-learning design, the researchers listened to the MP3 recordings repeatedly and noted the meaningful statements about u-learning, including keywords and ideas. We used Stake’s (1995) methods of ‘direct interpretation’ in Step 1, and ‘categorical aggregation’ in the next section of this work to analyse the data. Stake (1995) argues that, ‘two strategic ways that researchers reach new meaning about cases are through direct interpretation of the individual instance and through aggregation of instances until something can be said about them as a class’ (p.74). Direct interpretation was done by the researchers’ drawing preliminary conclusions based on the emerging themes and correspondences. Stake suggests that the researchers re-read the data, identify rival interpretations, and refine original interpretations accordingly. All the identified themes were further triangulated among three researchers of the present study to ensure the inter-reliability.

*Step 2: Sorting the Transcripts* (Löfmark et al., 2009): The researchers sorted the meaningful statements into different categories, as shown in Table 3.
<table>
<thead>
<tr>
<th>Creating thick descriptions</th>
<th>Giving meanings to the statements</th>
<th>Sources</th>
<th>References</th>
<th>Meaningful statements identified by the researchers</th>
</tr>
</thead>
</table>
| From the perspective of the personalized learning features that are derived from the u-learning contexts, the record of the learning process and the personalised learning environments and u-learning systems enable learners to control their learning schedules or set up their learning goals. The personalised learning goals and schedules help learners to better understand the learning materials. | U-learning systems record personal learning processes. | 2 | 8 | 'Your personal learning process is recorded by the system' (Participant 2).  
 'By examining your learning process, you can recall what you learned' (Participant 2).  
 'Researchers can find out the meanings of learners' behaviours by examining each learner’s learning process' (Participant 2).  
 'A learner’s process of answering questions is recorded, and researchers can analyse the process of answering questions to examine whether the questions are appropriate for the learners or not' (Participant 2).  
 'For example, when the u-learning system asks learners to take a picture of a specific learning object, each learner shoots the learning object from different angles. The researcher can observe these pictures from the u-system, and explore why the learners shot the object from different angles' (Participant 2).  
 'A learner can take his or her personal notes and record them by using the u-learning system' (Participant 4).  
 'The u-learning system provides some functions, and these enable learners take notes' (Participant 4).  
 'Learning portfolios are embedded in the u-learning system, and each learner’s learning process is recorded in a learning portfolio' (Participant 4). |
| | | 3 | 6 | 'A u-learning system provides formative assessments in different learning stages, and learners can reflect on their learning status and get adaptive feedback by doing these' (Participant 1).  
 'The u-learning system gives personalised navigation based on the learner’s learning process' (Participant 1).  
 'The personalised navigation from the u-learning system helps learners observe the learning object clearly, and learners can receive personalised feedback based on their learning processes' (Participant 1).  
 'The u-learning system adjusts the size and the colour of words automatically based on learners’ usage habits' (Participant 3).  
 'The u-learning system detects a learner’s position and gives the learning information based on learners’ current knowledge' (Participant 3).  
 'According to a learner’s learning stage, the learner receives the appropriate learning information and feedback from the u-learning system' (Participant 4). |
Table 3 Interview data about personalized learning features (continued)

<table>
<thead>
<tr>
<th>Creating thick descriptions</th>
<th>Giving meanings to the statements</th>
<th>Sources</th>
<th>References</th>
<th>Meaningful statements identified by the researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learners decide their learning goals and control their learning schedule based on their needs.</td>
<td></td>
<td>2</td>
<td>6</td>
<td>‘Each learner has a learning gadget, and he or she can control his or her learning schedule’ (Participant 1).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>‘Each learner can increase or decrease his or her learning time based on his or her needs’ (Participant 1).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>‘The mobility of the learning gadget allows a learner to cross temporal boundaries to adjust his or her learning time’ (Participant 1).</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>‘Each learner follows his or her learning schedule, since each learner has his or her own gadget’ (Participant 5).</td>
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<td>‘A learner can monitor his or her learning schedule by checking the record of learning process’ (Participant 5).</td>
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<td>‘A learner can set up a personalised learning goal’ (Participant 5).</td>
</tr>
</tbody>
</table>

Note: ‘References’ refers to the number of times the meaningful statements appeared in the interview data. ‘Sources’ refers to the number of participants who made the meaningful statement.
4.1.4 Giving meaning to the statements

‘Categorical aggregation’ was then performed by analysing the formative data from the interview transcripts, and categorising them based on the research questions. The researchers looked for recurring, emerging themes, using the interview questions as a guide, and tried to find correspondences among the themes to categorise similar statements (Stake, 1995).

For instance (see Table 3), the researchers put ‘provide adaptive assessment’, ‘give personalised navigation’, and ‘receive personalised feedback’ into the category of ‘personalised feedback’. Second, the researchers gave meaning to the statements, in this case ‘Learners’ receive personalised feedback from the u-learning system’.

4.1.5 Creating rich descriptions

To create rich descriptions, the researchers summarised the data by combining the concepts from the themes and subthemes, organised the structure of the data and developed a u-learning design model to explain the essence of the phenomenon (Löfmark et al., 2009).

5 Results and discussion

Using the categories proposed by Liu and Hwang (2010) as a basis, the present data on the u-learning phenomena were divided into five themes: personalised learning features, strategy-driven learning designs, u-learning environment and learner memory, u-learning environment and learning achievement, and u-learning environment and learner motivation. Personalised learning features and strategy-driven learning designs are related to tool applications, while learner memory, achievement and motivation are related to the learners’ internal perspectives (Liu and Hwang, 2010).

5.1 Theme A: identified personalised learning features

The following meanings related to personalised learning were given by the researchers in the interview data (see Table 3): ‘recording personal learning process’, ‘receiving personalised feedback’, and ‘controlling their learning process’. Moreover, the researchers concluded that both the record of the learning process including learning assessments and learning progress, and individualised feedback (such as location-aware and adaptive feedback), enable learners to control their learning schedule or set up their own learning goals. These personalised learning schedules and goals can help learners better understand the learning materials. In contrast to classroom-based learning environments, where learners have a limited amount of time to comprehend the learning materials, in a u-learning context learners can spend as long as they need until they comprehend them thoroughly.

5.2 Theme B: identified strategy-driven learning designs

Based on the participants’ perspectives, under the theme of strategy-driven learning designs, the researchers gave meanings to the statements, which were ‘collaborative learning strategies’, ‘giving procedural knowledge’, ‘task-based learning strategies’, ‘giving adaptive feedback’, and ‘situational learning strategies’. Strategy-driven learning
included collaborative learning strategies, task-based learning strategies, and situational learning strategies, and they are commonly found helpful for the design of u-learning, since the u-learning system gives information to learners instantly making it convenient share knowledge. Moreover, situational strategies are utilised since the system can construct an authentic learning environment for learners to receive procedural knowledge.

5.3 Theme C: identified u-learning environment and learner memory

In the theme of u-learning environment and learner memory, the meaningful statements were placed in the following categories: ‘the arrangement of u-learning activities’, ‘the record of learning process’, ‘the design of anchored instructions’, ‘interactions with the authentic environment’ and ‘the multi-input from gadgets’. Based on these, the researchers concluded that the arrangement of the activities and the anchored instructions increase the learners’ frequency of interaction with the environment, positively affecting learners’ recall. Moreover, the record function and the multimedia input improve learner memory.

5.4 Theme D: identified u-learning environment and learning achievement

The researchers put the statements about learning achievement in the u-learning environment into the following categories: ‘the design of activities’, ‘the authentic environment’, ‘wireless internet’, ‘the sensor technology’, and ‘learner cognitive load’. The researchers further synthesised these into the following conclusion about the u-learning environment and learning achievement where the design of learning activities increases learner cognitive load, and forces them to pay more attention to the activities, which positively affects their learning achievement.

5.5 Theme E: identified u-learning environment and learner motivation

Based on participants’ experiences, as related in the interviews, learners were motivated by the following factors: ‘the design of presenting learning materials’, ‘the attraction of the learning gadgets’, ‘the collaboration among peers’, and ‘knowing the learning purposes’. After identifying the components of learning motivation, the researchers concluded that in the initial learning stage, learner motivation is triggered by the learning gadgets, and knowing that learning activity enhances their learning. Thus, well-designed learning contents and competition among peers are crucial to enhance learner motivation.

Through analysis, we identified the essence of the u-learning phenomena, and transferred the vague experiences into clear concepts. In this study, the first research question aims to uncover the important sources of learning effectiveness in u-learning, and a u-learning design model is then developed in response to the second research question, serving as a reference for future studies.

5.6 Responses to RQ 1: what sources of learning effectiveness can be identified in u-learning?

The first source of learning effectiveness is personalised learning features, and this finding supports Low and O’Connell’s (2006) and Poslad’s (2009) conclusion that a u-learning platform is appropriate for use in learner-centred education, due to the
characteristics of adaptive feedback, instant information and highly portable gadgets. The emphasis on personal needs distinguishes u-learning from classroom-based learning, and learners become more self-directed in this context, with the learning effectiveness deriving not only from the learners pursuing their own personal learning goals based on their accumulated knowledge, but also from their self-regulation.

The second source of learning effectiveness in u-learning is strategy-driven learning design. Our findings indicate that u-learning allows learners to receive authentic information, which is appropriate for utilising collaborative and task-based learning strategies, and the significance of collaboration in a u-learning activity is based on giving real-time learning information and engaging in discussions with peers (Liu et al., 2008). For instance, Participant 4 examined his experiences and stated that organising competitions between peers is an effective way of improving learning achievement, rather than simply asking learners to work together.

U-learning activities are designed for task-aware and task-based learning, and thus specific knowledge elements are provided to the learners (Hwang et al., 2010). These specific knowledge elements increase learning effectiveness by lowering the cognitive load faced by learners. Moreover, scaffolding-supported learning and mastery learning (Huang et al., 2007) are strategies that are commonly used in u-learning. The u-learning system constructs a learning frame for learners, including how to observe and compare learning objects, take notes, and assess their learning. Learners follow a learning frame in the u-learning system, and once they have completed the u-learning activities they can utilise the same frame to learn other subjects. Further, a feature of some subjects is that learners are required to learn some procedural knowledge, and in u-learning activities learners have to follow the learning path and can thus obtain this procedural knowledge step-by-step, and this makes this approach suitable for educational training in some specific subjects, like nursing education.

The third theme in u-learning is learner memory. The features of a u-learning system include multiple inputs, the coherent arrangement of tasks, a record of the learning process, and interaction with the environment, all of which can aid learner memory. The multiple inputs and interactions with the authentic environment enable learners to connect their sensory memory to their long-term memory. With contextual interaction improving the effectiveness of recall (De Jong et al., 2007), the participants stated that the appropriate framework of the learning design includes coherent tasks and a learning portfolio. The use of a logical system underlying learning tasks, such as following the chronological order of historical events, is beneficial for memorisation. Moreover, learners can trace their learning assessments and processes via learning portfolios, and the records contained in these can also aid memorisation.

The key step in moving knowledge from the short-term to long-term memory is related to mastering a task, and in a traditional learning environment it is not possible for instructors to teach the same lesson repeatedly. However, the u-learning design allows learners to practise the same task several times in a student-centred learning sequence, which helps them to develop their long-term memory and increases learning effectiveness.

The fourth theme is learning achievement in a u-learning setting, which is derived from the authentic environment. Sensor technology and wireless internet are key factors in obtaining an authentic environment. Sensor technology, like RFID tags, can send information to learners when they need it. In addition, learners can become more immersed in the environment when they are searching for tags and they need to complete a task (Liu and Chu, 2010). Once learners find a tag, they can extend their learning from
reading to observing and touching the learning objects. However, one of the participants in this study indicated that not all subjects are suitable for use with sensor technology, which is more appropriate for practical courses, such as laboratory work, cooking, and those that make use of specific machines.

The wireless internet allows learners access to instant feedback (Chiou et al., 2010), as well as the ability to exchange information and share their reflections, thus constructing knowledge with peer support, and in this way learners can obtain more chances to clear up any ambiguities they encounter. However, designers should pay attention to the usability of the wireless internet, as when the learning will take place in an outdoor environment the connection should be stable, as loss of the ability to go online will hamper learning effectiveness.

The fifth theme is learner motivation in u-learning, and this is triggered by the learning gadgets and also by a meaningful learning purpose and well-designed learning materials. This finding is supported by Keller’s (2008) principles of motivation, which stated that curiosity can increase learners’ attention, and that curiosity originates from learners’ perceptions of the gap between the learning object and their current knowledge. In other words, learners should perceive that they do not have the relevant experience in a specific u-learning activity, as this will raise their curiosity, and the use of u-learning gadgets and designs will then further increase their motivation. Once learners are familiar with u-learning, knowing the learning purpose enables them to perceive the meaning of their learning goals, and this also increases their motivation (Keller, 2008). Further, u-learning requires learners’ self-control to complete the learning tasks and to continue to make an effort to achieve their learning goals, and well-structured and rigorous materials can reinforce learning effectiveness.

5.7 Responses to RQ 2: based on the sources of learning effectiveness identified in response to RQ 1, what is an appropriate learning design model for u-learning?

We summarised the main points and developed a learning design model for u-learning based on the sources of learning effectiveness in u-learning identified in this work, as shown in Figure 2. The u-learning process has two phases; in the first, the u-learning system creates personal learning features and strategy-driven learning as the external input for learners. In the second phase, learners benefit from u-learning and retrieve information about learning materials from their memory, and then are able to obtain more learning achievements, and hence feel greater learning motivation in a u-learning project. Therefore, the effectiveness of u-learning is related to the use of a personalised learning features and the utilisation of learning strategies. Learners’ memorisation, achievement and motivation are all enhanced by the learning environments and strategies associated with u-learning.

6 The learning design model for u-learning

In this section, we describe the factors that affect learning effectiveness and illustrate the relationships among them. We categorised the factors in the u-learning design model into two phases (see Figure 2): the external input from u-learning and the internal learning frame for u-learning learners.
6.1 External input from u-learning

The focus of this phase is the material provided by designers or instructors, based on their experiences and suggestions mentioned in the interview process. The purpose for the input is to construct a good connection to the learners’ internal learning frame. In the u-learning design phase, instructors should identify learners’ learning preferences to maximise the personalised learning features with presage and context variables (Beatty, 2010; Dunkin and Biddle, 1974) that are derived from the u-learning context. Beatty (2010) identified learners’ experiences and characteristics as one of the context variables which influence their learning behaviours, such as their previous experience using technology and their acceptance of new learning tools.

The learners’ learning characteristics can be identified by an investigation of their learning preferences, current knowledge, and intentions (Hummel et al., 2004). After clarifying learners’ learning preferences, designers then design applications that correspond to these. For example, the u-learning system can give adaptive feedback to learners according to their prior knowledge, and provide specific learning paths based on their intentions. In this study, Participant 1 stated that ‘the u-learning system gives personalised navigation based on the learner’s learning process’, and ‘is appropriate for learners to develop their own learning process’. Participant 3 further stated that ‘The u-learning system adjusts the size and the colour of words automatically based on learners’ usage habits’, which creates learners’ personalised learning (see Table 3).

In addition to the consideration of learners’ features, Beatty (2010) further suggested that community is one factor that belongs to context variables and is one of the external inputs, since instructors can get further understanding of learners’ features via
observation of their interactions in a community. In the context of u-learning, there will be various kinds of interaction that need further exploration, such as the human–computer interaction that occurs via the sensor triggered devices, the anytime and anywhere online interaction, and the constructed environmental interaction.

When the learners undertake the learning activities, strategy-driven learning with process variables helps them to engage in this (Beatty, 2010; Dunkin and Biddle, 1974). The sequence from personalised learning features to strategy-driven learning leads learners from awareness of their learning styles to adoption of appropriate learning strategies (Brown, 2007a). Instructors might consider the personalised learning features thus designed and types of subjects being learned to offer more appropriate learning strategies. For instance, field dependent learners, who easily perceive the whole field of input, including the interaction of the environment and peers (Brown, 2007b), may adopt situational and collaborative learning strategies. Instructors can therefore develop a u-learning design with more situational features and add more interactional tasks for field dependent learners. For instance, Participant 2 stated that ‘when learners are situated in the real situation, they will learn something unconsciously’, and the situational features thus assist learners in gaining knowledge. Participant 3 further suggested that ‘learners will be immersed in the authentic environment via the u-learning system’.

Moreover, Beatty (2010) defined instructors’ experiences and professional knowledge for instructions as presage variables, which predominate the design and development of teaching and learning, and these variables are external inputs to learners. In terms of the instructors’ experience and knowledge, what they have gone through in training and teaching influences the online learning system and the choice of learning strategies that they can offer to learners (Beatty, 2010).

From the learner’s perspective, learner behaviour is one of the key variables (Beatty, 2010), and in the learning process they utilise various strategies based on their level of knowledge (Beatty, 2010). Therefore, the learning strategies that learners receive from instructors in the pre-learning stage and the strategies they actually adopt in the learning process positively or negatively affect their acquisition and comprehension of the knowledge.

6.2 Internal learning frame for learners in u-learning

The key notion of the internal learning frame is how learners engage in u-learning, how they develop their knowledge, and how each factor in the internal learning frame interconnects with the others, and a better understanding of the learners’ learning sequence will help instructors to develop learner autonomy (Brown, 2007a). Learner memory is promoted through well-designed features and strategies, such as adaptive and personalised feedback, which corresponds to the learners’ current learning stage, and facilitates both comprehension and memorisation. Additionally, learners receive various intensifiers through the application of learning strategies, which also facilitate memorisation, like audio-visual input from situational learning strategies, and communicative input from collaborative ones. For example, Participant 4 stated that ‘the gadgets provide multimedia input to learners to assist their recall of information’, while Participant 5 said that ‘the gadgets give learners not only textual information, but also pictures, and the varied input improves learner memorization’. Experienced u-learning designers also agreed that the u-learning setting positively influences learners’ memorisation.
The processes by which learners perceive and recall information affect their learning achievement (Brown, 2007b). That is, external input and learner memory contribute to learning achievement. For example, Participant 1 stated that ‘learners master the learning materials by the design of u-learning activities’, and ‘the mastery of a skill brings learning achievement to learners’. Further, Participant 2 said that ‘learners are allowed to observe the real learning objects in the authentic environment, and this enhances their learning achievement’, and hence learning achievement is connected with the outputs from u-learning settings and designs. U-learning designers are thus encouraged to create meaningful input reinforcing learner memory and learning achievement. For example, the design of a learning path should follow temporal logic, as this helps learners in the organisation and memorisation of learning materials. Higher learning achievement reveals the possibility of greater learning motivation. The rich knowledge and achievement learners gain from undertaking the u-learning tasks, such as exploration and the acquisition of skills, can trigger and sustain their learning motivation.

Beatty’s (2010) model for the study of multimedia learning materials, based on Dunkin and Biddle’s (1974) classroom teaching model, considers product variables as the output from learners, including elements such as ‘observable changes in learner behaviour’, ‘immediate learner growth’, and ‘long-term learner effects’ (Beatty, 2010, p.144). In this study, the researchers consider learning achievement as the learners’ immediate growth receiving u-learning support, and the accumulation of such growth brings long-term positive learner effects, like enhanced memory of the material. Learners’ behavioural changes derive from their learning motivation, since if they have a positive learning experience then this will make them more willing to repeat the same behaviours.

For u-learning instructors and designers, it is worth considering how to enrich the learning materials to maintain the attraction of learning. For instance, when the target learners are adults, the design of learning materials and activities would not be limited to the transfer of declarative knowledge, but instead should include procedural knowledge. Once learners’ motivation is inspired and sustained, they will be willing to receive the external input from u-learning, continuing their autonomous learning. Furthermore, instructors and designers can observe learners’ internal learning frame from diverse perspectives, such as assessments after learning activities, how learners engage in their learning, and what they do in their learning process (Beatty, 2010; Liu et al., 2016b). All of these things can be considered as reflections on u-learning, and are important for learners, instructors, and designers to compare and contrast what factors impede or encourage learning, thus aiding the future development and practice of this new pedagogical approach.

7 Conclusions

The phenomenological research method was used in this work to identify the participants’ empirical experiences with u-learning and u-learning design. In order to better understand the current progress of learning technology, the researchers collected data by interviewing u-learning designers to obtain a better research design (Liu, 2008). This study presents a learning design model and the main sources of learning effectiveness in u-learning based on the idea that u-learning can improve learning effectiveness and that educators can benefit from the analysis of u-learning designs.
Through these new learning activities, multiple learning dimensions, like collaborative or inquiry-based learning, are expected to develop and allow learners to engage in more interesting and effective learning environments.

The results indicate technological innovations can lead to pedagogical paradigm shifts in learning (Enriquez, 2011; Greenhow et al., 2009; Greenhow and Robelia, 2009; Jonassen, 2004; Liu and Hwang, 2010), such as breaking institutional spatial or temporal boundaries, generating productive resources, and broadening representational modes (Cope and Kalantzis, 2010). U-learning is a technological innovation in education, and there are still many areas of inquiry worthy of exploring in this emerging field (Barrett and Liu, 2016; Hwang and Tsai, 2011; Liu and Hwang, 2010; Wang et al., 2016).

For future studies, it is suggested that a similar method be used to examine learners’ experiences within the u-learning setting since reflections can help to improve this new approach to teaching (Hsieh et al., 2011; Liu et al., 2014b; Wang et al., 2016). Researchers are also encouraged to explore the relevant variables, such as interoperability, in applications or research focused on u-learning (Hwang and Tsai, 2011; Liu and Hwang, 2010; Liu et al., 2015), the evaluation criteria for u-learning designs in language development (Liu et al., 2011), or in other academic fields with regard to both language learner perspectives and experiences (Liu et al., 2016a; Liu et al., 2016b; Wang et al., 2016). Furthermore, it is both important and challenging to develop new measurement tools to investigate the effects of applying existing educational theories or learning strategies to the learning performance of students in a u-leaning environment (Liu et al., 2014b; Tsai et al., 2012).

References


Identifying learning features and models


Identifying learning features and models


