Mindtool-Assisted In-Field Learning (MAIL): An Advanced Ubiquitous Learning Project in Taiwan

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ABSTRACT

Scholars have identified that learning in an authentic environment with quality contextual and procedural supports can engage students in thorough observations and knowledge construction. Moreover, the target is that students are able to experience and make sense of all of the learning activities in the real-world environment with meaningful supports, such that their learning motivation can be promoted, knowledge can be sensibly constructed, and skills can be fully developed. To develop potential tutoring strategies and learning activity models using mobile, wireless, and sensing information and communication technologies (ICT) in a real-world learning environment, a four-year national e-learning research project entitled “Mindtool-Assisted In-field Learning (MAIL)” has been funded by the National Science Council of Taiwan since 2008 in an effort to lead the development and innovation of Learning Technology. The integrated project aimed to develop Mindtool-assisted knowledge construction models, assessment models, guidance models, and reflection strategies for cutting-edge context-aware ubiquitous learning. Moreover, a series of learning activities has been conducted to examine the effectiveness of the proposed learning strategies and models. Each year, more than 1,500 students have participated in the in-field learning activities with the designed approaches. Based on the results of a series of experiments, it was found that the students’ learning performance as well as their in-field inquiry ability was significantly improved, showing the effectiveness of the Mindtool-assisted ubiquitous learning approach and the success of the MAIL project. In this paper, the background, objectives, theoretical foundations, systems, research issues, applications, and findings of the MAIL project are presented. Finally, the scaling-up plan for applying these research-proven learning models to all levels of educational settings in Taiwan is also addressed.

Keywords

Mobile learning, Ubiquitous learning, Mindtools, Concept maps, Repertory grid

Background and objectives

Learning Technology (LT), as a trans-disciplinary, professional field of leading human developments and innovations in various situations, disciplines, settings, and industries with advanced technological uses, is always in need of creative applications of hard and soft technologies in order to bring about positive changes (Jonassen, 2004; Liu, 2008). Many educators have identified the importance of situating students in real-world contexts for developing and acquiring knowledge and skills (Brown, Collins, & Duguid, 1989; Lave, 1991; Wong & Looi, 2011). In the meantime, researchers have also pointed out the importance of providing personalized learning supports or knowledge sharing facilities during in-field activities (Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2009; So, Seow, & Looi, 2009). The popularity of mobile and wireless information and communication technologies (ICT) has provided good opportunities which match this emerging trend in LT; moreover, the advancement of sensing technology has further enabled learning systems to detect real-world information with various types of information-generating e-readers and e-tags. With the help of these technologies, students are able to learn anytime, anywhere. That is, they are encouraged to learn in various real-world environments with supports from and access to the digitalized world (Hwang, Tsai, Chu, Kinshuk, & Chen, 2012; Looi et al., 2009; Wong, 2012); moreover, dynamic learning systems are developed for the user to engage in more active interactions with other learners as well as the learning system itself (Ogata, Li, Hou, Uosaki, El-Bishouty, & Yano, 2011; Okamoto & Tseng, 2008). Generally speaking, this kind of learning strategy has been called “context-aware ubiquitous learning,” and is a state-of-the-art, particular form of ubiquitous learning (u-learning) as defined by Hwang, Tsai and Yang (2008).

Recently, context-aware u-learning has become a popular issue and research topic in the area of e-learning (Ogata & Yano, 2004; Sollervall, Otter, Milrad, Vogel, & Johansson, 2012; Syvänen, Beale, Sharples, Ahonen, & Lonsdale, 2005). Researchers have attempted to conduct context-aware u-learning activities for various courses; however, it
has been found that, without effective learning strategies or tools, students’ learning performance could be disappointing (Chu, Hwang, & Tsai, 2010; Chen & Li, 2009; Liu, Peng, Wu, & Lin, 2009). Several studies have pointed out that u-learning scenarios could be too complex for most students without some proper guidance or supports, because the students need to make use of both real-world and digitalized world learning resources at the same time (Shih, Hwang, Chu, & Chuang, 2011). Therefore, it has become an important and challenging issue to provide effective learning supports in mobile or ubiquitous learning activities.

Among the various learning strategies and tools, Mindtools have been recognized as an effective way of assisting students to learn in complicated learning contexts with all kinds of ICT. Educators have indicated that “technologies should not support learning by attempting to instruct the learners, but rather should be used as knowledge construction tools that students learn with, not from” (Jonassen, Carr, & Yueh, 1998, p. 1). Mindtools are cognition tools that are able to assist students to think and learn in a meaningful and constructive way through stimulating them to expand their cognitive ability in interpreting, analyzing, synthesizing and organizing their knowledge. Jonassen (1999) defined Mindtools as “a way of using a computer application program to engage learners in constructive, higher-order critical thinking about the subjects they are studying” (p. 9). With the assistance of Mindtools, students’ knowledge can be constructed to reflect what they have learned and realized, instead of merely memorizing or recalling content taught by their teachers.

Mindtools and their logical learning design have been widely developed and used with various computer-based application programs, which include database systems, spreadsheets, expert systems, semantic nets (e.g., concept maps), video conference systems, multimedia and hypermedia editing tools, programming tools, and Microworld environments (Jonassen, 1999). In the past two decades, scholars all over the world have paid much attention to using Mindtools in various practical applications related to in-class learning, blended learning, and totally online learning; nevertheless, using Mindtools in u-learning activities remains an important but challenging issue (Lee, Lee, & Leu, 2009).

To develop Mindtool-supported u-learning approaches and to investigate their effectiveness, a four-year national e-learning project was initiated in Taiwan in 2008. The aim of the project was to develop Mindtool-assisted u-learning environments and strategies. Numerous experiments were conducted to evaluate the effectiveness of applying the Mindtool-assisted u-learning approaches to various in-field activities in terms of students’ learning achievement, motivation, attitudes, cognitive load and technology acceptance. Moreover, the students’ in-field observation and question-raising abilities were measured as well.

**Mindtool-assisted ubiquitous learning approaches**

To facilitate in-field learning within context-aware u-learning environments, two kinds of Mindtools were developed to support u-learning activities in the integrated, collaborative project; that is, the grid-based approach which originated from a knowledge elicitation method for developing expert systems and the concept mapping approach that has been widely adopted in in-class learning, blended learning and totally online learning environments.

**Grid-based Mindtools for ubiquitous learning**

An expert system is a computer system that simulates expert-level reasoning based on the knowledge elicited from domain experts. The process and know-how of acquiring and organizing knowledge from domain experts for building knowledge bases of expert systems is called knowledge engineering (Feigenbaum, 1977). Jonassen (1999) indicated that such a process of collecting and organizing domain knowledge for constructing knowledge bases could engage students in critical thinking; that is, an effective way of employing expert systems as Mindtools is surely to engage students in collecting and organizing knowledge related to the course/learning content they aim to learn following a knowledge acquisition approach.

Among various knowledge acquisition approaches, the repertory grid method originating from the Personal Construct Theory proposed by Kelly (1955) has been widely adopted and discussed (Aranda-Mena & Gameson, 2012; Canning & Holmes, 2006; Boose & Gaines, 1989). A repertory grid can be viewed as a matrix whose columns are element labels and whose rows are construct labels. Elements could be decisions to be made, objects to be
identified, or concepts to be learned, while constructs are traits for featuring the similarities or differences between
the elements. A construct consists of a trait (e.g., “Long”) and the opposite of that trait (e.g., “Short”). Meanwhile, a
five-scale rating mechanism is usually used to represent the relationships between the elements and the constructs,
where “1” represents that the element is inclined to have the trait and “5” represents that the element is inclined to
have the extreme opposite characteristic of that trait.

Referring to the “Expert systems as Mindtools” conception proposed by Jonassen (1999) and the repertory grid
method, a repertory grid-oriented Mindtool was developed in the MAIL project for supporting in-field ubiquitous
learning in several ways. In the earlier stage of this project, the repertory grid-based ubiquitous learning system was
used as a guiding system for helping students observe learning targets in the field, collect data based on their
observations, and develop repertory grids for organizing the collected data. Since 2008, a series of learning activities
has been conducted with the tool to help students identify and classify a set of learning targets (e.g., plants on a
school campus, butterflies in ecology gardens, or rocks in laboratories) via guiding them to observe the learning
targets and organize what they have found in a repertory grid using mobile devices (Chu, Hwang, & Tsai, 2010; Wu,
Hwang, Su, & Huang, 2012).

Before the learning activities, teachers were asked to develop an objective repertory grid (i.e., a repertory grid with
correct ratings for each <element, construct> pair) to guide the students to make observations in the field and develop
their own repertory grids. In such a learning-guiding approach, the elements and constructs were provided by the
teachers; therefore, the students only needed to fill in the rating for each <element, construct> entry based on their
observations in the field. Users were encouraged to consider the objective repertory grid in Table 1, in which the
elements were "Lalang Grass," "Arigated-leaf croton," "Cuphea," "Indian almond," "Money tree," "Crown of
thorns" and "Pink ixora," and the constructs were "leaf shape," "leaf point," "leaf edge," and "number of leaf vein
branches." For example, the value of the <Lalang Grass, Leaf-shape> entry is 1, indicating that the leaf shape of
Lalang Grass is "Long and thin." On the contrary, the value of the <Indian almond, Leaf-shape> entry is 4, implying
that the leaf shape of Indian Almond tends to be "flat and round."

### Table 1. Example of a repertory grid for guiding students to observe plants on a school campus

<table>
<thead>
<tr>
<th>Trait</th>
<th>Lalang grass</th>
<th>Arigated-leaf croton</th>
<th>Cuphea</th>
<th>Indian almond</th>
<th>Money tree</th>
<th>Opposite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf-shape long and thin</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>Leaf-shape flat and round</td>
</tr>
<tr>
<td>Perfectly smooth leaf edge</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>The leaf edge has deep indents</td>
</tr>
<tr>
<td>The leaf vein has few branches</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>The leaf vein has many branches</td>
</tr>
</tbody>
</table>

During the learning activities, the students were asked to complete their own repertory grids by filling in the rating
for each <element, construct> pair based on their observations in the field. If the students failed to give the correct
ratings in comparison with those given by the teachers in the objective repertory grid, the learning system would
guide them to observe a comparative learning target with the “incorrect main-feature” and would ask them to
compare it with the original learning target. For example, if a student observed the plant (learning target) “Lalang
Grass” and described its “Leaf point” as “round with a blunt tip” (by giving rating “4”), by comparing the student’s
answer with the rating given by the teacher (i.e., “tapering to a long point” with rating “2”), the learning system
detected that the student’s answer was incorrect. Accordingly, the learning system tried to find a comparative plant
with “round with a blunt tip” leaf points from the objective repertory grid. In this case, “Indian almond” met the
condition; therefore, the student was guided to observe the “Indian almond,” and compared its “Leaf point” with that
of “Lalang Grass,” as shown in Figure 1. Having made the comparison, the student was then asked to answer the
question again. If the student still failed to correctly answer the question, the learning system then provided
supplementary materials and the teacher’s rating to the student.

In addition to the guidance from the learning system, the students were able to browse their own repertory grids via
the mobile device during the field trips, which was helpful to them in identifying and distinguishing the learning
targets via comparing the corresponding ratings of the features of the targets in the grid.
The student is asked to observe the leaf shape of "Indian almond" and compare it with the leaf point of "Lalang Grass". The answer "Round with a blunt tip" to the "leaf point" of "Lalang Grass" is incorrect.

To engage students in higher-order thinking during the in-field learning activities, the repertory grid-based Mindtool has further been used to support collaborative knowledge construction in context-aware ubiquitous learning activities in the MAIL project. For example, one of the applications conducted in 2010 aimed to engage students collaboratively in a more challenging learning task; that is, the teacher only showed them the learning targets/objects (i.e., plants on the school campus) without providing any other guidance during the in-field learning process, meaning that the students needed to determine the constructs for identifying and differentiating the plants themselves as well as observing the plants and collecting data. To enable the students to share their repertory grids and make reflections after referring to the repertory grids developed by their peers, a knowledge-sharing system was developed. Through this knowledge-sharing system, the students could upload their repertory grids to the system, browse others' repertory grids, receive feedback from teachers, and discuss with their peers. The experimental results showed that the quality (i.e., completeness and correctness) of individual students' knowledge structure (i.e., the constructs they used and the ratings they gave to represent the relationships between elements) was significantly improved after the ubiquitous learning activity.

Concept mapping as Mindtools for ubiquitous learning

Concept mapping is a well-known learning tool for helping students organize and visualize knowledge and learning experiences (Chiou, 2008; Fischer, Bruhn, Grasel, & Mandl, 2002; Hwang, Wu, & Kuo, 2013; Novak & Cañas, 2006). It is also an effective assessment tool for helping teachers evaluate students' cognitive levels and knowledge structures (Ingeç, 2009; Liu, Don, & Tsai, 2005; Peng, Su, Chou, & Tsai, 2009; Trent, Pernell, Mungai, & Chimedza, 1998). In the past decades, many studies have shown the effectiveness of concept mapping in engaging students in meaningful learning, and hence their learning achievements could be improved (Amadieu, Tricot, & Mariné, 2010; Anderson-Inman & Ditson, 1999; Horton et al., 1993; Markham, Mintzes, & Jones, 2006).

In the MAIL project, concept mapping has been employed in context-aware ubiquitous learning activities in several ways. For example, one of the learning activities was conducted for butterfly ecology observations. Before the learning activity, the students were asked to develop a concept map about butterfly ecology based on what they had learned from the textbook. During the in-field observations, the students browsed their concept map when observing the butterflies in the ecology garden. They could modify the concept maps if something different or interesting was observed. Alternatively, they could take notes and modify the concept maps when they went back to the classroom. Figure 2 shows the scenario of the in-field learning activity. The students were situated in the butterfly ecology garden with wireless communication networks. The garden consisted of 25 ecology areas in which particular kinds of butterflies and the related host plants of the butterflies are raised. In this earlier study, an RFID (Radio Frequency Identification) tag was placed in each ecology area and each student held a PDA (Digital Personal Assistant) with an RFID reader. When the students walked into an area, the learning system could detect the information within the tag in that area via the RFID reader and confirm individual students’ locations, such that corresponding learning guidance or support could be provided.
In recent studies of the integrated MAIL project, smartphones and the QR-code sensing technology have been used to support extensive self-directed learning in the field. A series of large-scale and long-term activities has been conducted in Chiku Ecology Park in southern Taiwan, where various species of mangroves grow. Figure 3 shows the plan for one of the learning activities. In this activity, the students were equipped with a smartphone to interact with the learning system as well as a telescope for long-distance observations. The learning system provided online instant feedback (e.g., hints to remind the students that part of their answers to the questions raised by the learning system were incorrect) and learning guidance (e.g., clues to find the correct answers to the questions) to the students via wireless communications. Moreover, an e-library was developed to provide supplementary materials for the field-based activities.

A series of concept mapping tasks was developed to scaffold the students’ knowledge construction during the field trips in a progressive manner. In the first stage, the learning tasks included multiple-choice questions, short-answer questions, and a structured two-level concept map in order to help the students clarify their knowledge about the basic features of individual mangrove species. In the second stage, the learning tasks were designed to encourage the students to describe the advanced features for classifying different species via the use of developing multiple-level concept maps. In the third stage, the learning tasks aimed to guide the students to compare the species and find the relationships among the species based on what they had learned and observed via developing the multiple-level and cross-relationship concept maps.
Figure 4 shows an illustrative example of a student’s emerging concept map while working in the field. The title of the concept map is “the life of Idea leuconoe clara,” which is a species of butterfly found in Taiwan. Before the field trip, the student developed an initial concept map consisting of four stages (i.e., egg, pupa, larva and imago) to describe the life of Idea leuconoe clara. Later, he went to the butterfly garden to complete the learning tasks. When observing the butterfly ecology in the field, the student browsed the initial concept map and found several facts to be added: (1) In stage 1 of the Idea leuconoe clara, he had only described the egg as being “white or lemon yellow;” however, in the field, he noted that the egg was also “translucent.” Therefore, this new feature was added to the concept map, as shown in block A of Figure 4. (2) In stage 2 of the Idea leuconoe clara, he had not described the features of the larva. When learning in the field, he noted two of its features, that is, “red spots on the sides of the body” and “black and white;” therefore, these two features were added to the concept map, as shown in block B of Figure 4. (3) In stage 4 of the Idea leuconoe clara, he had not given examples of food plants. When observing in the field, he found that the Idea leuconoe claras were acquiring honey from magnolias; therefore, the proposition “magnolia is an example of food plants” was added to the concept map, as shown in block C of Figure 4.

![Figure 4. Example of a students’ emerging concept map while working in the field](image)

**Applications and research items**

From August 1, 2008 to September 30, 2012, the research team conducted 73 u-learning activity-based studies to try out the learning system, Mindtools, learning models and strategies, evaluation scales, and the design of the learning content and activities. The in-field learning environments included the Chiku Mangrove Conservation Area, the Chiku Black-faced Spoonbill Conservation Center, the butterfly ecology garden in Cheng-Kung Elementary School, the science parks and museums in several cities across Taiwan, and the campuses of several educational settings in Taiwan. The learning content of the in-field activities not only focused on natural science, but has also been extended to various academic disciplines. So far, there are 38 natural science studies, 19 social science studies, 5 computer science studies, 2 nursing training studies, 7 language learning studies, 1 mathematics study and 1 Art learning study conducted as part of the MALL project.

The total number of participants has increased each year, from about 500 participants in 2008 to nearly 3,000 in 2012, as shown in Figure 5. To date, the total number of participants in this integrated LT project has reached more than 6,000 students. Most of these experiments have been conducted by comparing the learning performance of experimental groups and control groups; moreover, the students’ pre-and post-test scores as well as their perceptions collected based on several measures have been analyzed. It is evident that based on these experiment results, both the
quantity and quality of this integrated, collaborative research project are satisfactory in terms of academic rigor and knowledge innovation.

![Number of participants](image)

**Figure 5.** The number of students participating in the MAIL ubiquitous learning studies in 2008-2012

### Achievements and implications

In the early experiments, we aimed to investigate the students’ perceptions of learning with the ubiquitous learning approach in comparison with their past experiences of learning with the traditional one-to-many in-field instruction. In the meantime, the teachers’ perceptions of conducting u-learning activities were also investigated. For example, one of the experiments was conducted to collect the feedback from 30 elementary school students and 9 teachers after they experienced a u-learning activity in the butterfly ecology garden (Peng et al., 2009). From the questionnaire survey, it was found that, in comparison with the traditional instruction, the students’ learning motivation and interest were significantly promoted with the help of the personalized guidance and feedback provided by the u-learning system in the field. The average rating given by the students was 4.53 in a five-point Likert rating scheme. Moreover, from the interviews, it was found that the teachers highly accepted the u-learning approach owing to several reasons: (1) it provided the students with better access to online resources during the field trip; (2) it enabled the students to make observations and collections with learning guidance without being constrained by time or location; (3) the u-learning activities engaged the students in learner-centered activities seamlessly across locations and contexts; and (4) the u-learning approach was able to provide step-by-step expert advice and record the students’ learning portfolios.

To improve the students’ learning achievements, in the second stage of the MAIL project, we aimed to compare the effectiveness of the Mindtool-assisted in-field learning approaches with that of the conventional tour-based u-learning approach, which guides individual students in the field, providing them with supplementary materials and giving feedback to them based on their observations and input. It was found that, with the assistance of the Mindtools, the students’ learning achievements, as well as their learning attitudes, were significantly improved. Moreover, it was also found that via the sharing of the constructed knowledge (e.g., repertory grids or concept maps), the knowledge structures as well as learning achievements of the students were further improved. For example, in an experiment for conducting a “plant identification” activity at an elementary school campus, the repertory grid method was implemented in the u-learning system to serve as a Mindtool to help the students summarize the features of the plants observed in the field (Chu, Hwang, & Tsai, 2010). From the experimental results, it was found that the Mindtool-integrated approach not only enhanced the learning interest (the average rating changed from 4.85 to 5.31 in a six-point Likert rating scheme), but also improved the learning achievements in comparison with the conventional u-learning approach via ANCOVA analysis \( F = 9.573, p = 0.011 \) and \( d = 1.39 \) for the two groups of students. Another experiment was conducted in the butterfly ecology garden with embedded concept mapping in the u-
learning system to help students organize what they had observed in the field and compare the acquired knowledge with their prior knowledge learned from the textbooks (Hwang, Shi, & Chu, 2011). The experimental results showed that, after the learning activity, the students who learned with the Mindtool-based u-learning approach showed a significantly positive change in their attitudes toward learning science (from an average rating of 3.97 to 4.38 in a five-point Likert rating scheme); moreover, their learning achievements were significantly improved in comparison with the achievements of those who learned with the traditional concept maps (with paper and pencil) in the field and the conventional u-learning approach based on the ANCOVA result ($F = 4.257, p < 0.05$).

In the third stage of the MAIL project, Mindtool-integrated u-learning was included in the formal science curriculums of several selected schools in Taiwan. Accordingly, several long-term activities were conducted in field trips to observe the growth of students’ inquiry competences with the u-learning approach, such as problem-posing and problem-solving abilities. For example, in one of the activities conducted in the Chiku Ecology Park, the participating students were forty-nine elementary school students aged 11.5 years old on average. The students experienced the field trips within four months to complete a series of learning tasks. Twenty-five of them who were assigned to the experimental group learned with the u-learning approach. Another twenty-four students who were the control group learned with the traditional in-field instruction; that is, they were guided and instructed by the teacher on the field trip. The students’ inquiry performances were evaluated by the teachers based on several criteria, including the quantity and accuracy of the descriptions of the learning targets for completing the learning tasks, the number and quality of the questions raised and the responses to the peers’ questions during the field trip, and the relevance and correctness of the features and relationships used to describe their findings in the learning diaries. It was found that through the assistance of Mindtools, the students’ inquiry behaviors, such as the quantity and quality of the questions they raised and the depth of their descriptions of their observations in the field, were significantly increased in comparison with traditional in-field learning based on the ANCOVA result ($F = 4.72$ and $p < 0.05$); in the meantime, the students’ learning performances were significantly improved.

Another three-month experiment was conducted to compare the learning performance of 18 gifted students and 30 average students who were 11.5 years old on average. The participants were scheduled to learn with the concept map-based u-learning approach in the Chiku Ecology Park. Within the three months, the two groups of students showed remarkable progress in ecology observations based on the Computerized Ecology Observation Competence Assessment (CEOCA) developed by Hung, Hwang, Lin, Hung and Wu (2010). The CEOCA consisted of three facets, that is, knowledge, observations and conceptual relationships. The test items were presented with real pictures, films or concept maps. In the pre-test, the average performance of all of the participants was close to the norm (0.04 vs. 0.00) of the students of the same age in Taiwan. After the learning activity, the post-test scores showed that the average growth slope of all of the participants was significant ($\mu = 0.27, p < .01$) in comparison with their pre-test scores with effect 0.53; however, there was no significant difference between the two groups. By conducting a follow-up test one month later, a significant difference was found in the CEOCA scores between the two groups. The gifted students revealed positive performance growth, while the performance of the average students decayed after the learning activity, showing the need to provide continuous supports to average students after field trips (Hung, Hwang, Lin, & Su, 2012).

Furthermore, some experimental results also showed that the Mindtool-assisted u-learning approach can help students improve not only their learning achievements, but also their higher-order critical thinking competences. For example, in one of the u-learning activities conducted in the butterfly ecology garden, the students were asked to develop repertory grids based on what they observed on the field trip (Hwang, Chu, Lin, & Tsai, 2011). The experimental results showed that the students who learned with the Mindtool-based u-learning approach showed better learning achievements than those who learned with the conventional u-learning approach. By comparing the students’ answers to the learning sheets before and after participating in the repertory grid-based u-learning activity using a t-test, it was found that the students’ ability of determining the characteristics for differentiating the butterflies and their competence for identifying and differentiating the butterflies had significantly improved with $t = 7.13$ ($p < 0.001$) and $t = 9.23$ ($p < 0.001$), respectively. This implies that their higher order thinking (i.e., analysis and evaluation) performance was improved.

In addition to the lead-in of various Mindtool-based u-learning strategies, it should be noted that some of the participating schools of the MAIL project have already included such Mindtool-assisted u-learning approaches as part of their regular curricula. For example, a nursing school in southern Taiwan not only prepared their own u-learning equipment (i.e., mobile devices, wireless networks and sensing devices) after participating in one of the
experiments of the MAIL project, but also started to use the repertory grid-based u-learning approach as a standard way of teaching some clinical nursing courses.

Another issue raised in the MAIL project was the cognitive load of the students who participated in the u-learning activities (Hwang, Wu, Zhuang, & Huang, 2013). As the students needed to interact with the real-world learning environment as well as the e-learning system simultaneously, there was a concern that their cognitive load might be too great in some cases; therefore, several experiments of the MAIL project measured the students’ cognitive load using the measures developed by Paas (1992) and Sweller, van Merriënboer, & Paas (1998). It was found that, with a proper learning design, the Mindtool-assisted u-learning approach could significantly decrease students’ cognitive load; on the contrary, students were likely to meaningfully expand their cognitive capability after the practice of integrating in-field observation and technology-driven knowledge construction into situated learning. This decrease could be due to the fact that the Mindtools were able to assist the students in organizing the collected data from the field by linking the chunks of information in a well-structured form, which eased their load in interpreting the data (Verhoeven, Schnotz, & Paas, 2009). For example, the repertory grid-based Mindtools can help students organize the observed features of the learning targets in a unified form (i.e., ratings ranging from 1 to 5), which is very helpful to them for comparing the learning targets and identifying the significant features that can be used to distinguish the targets. Consequently, students’ cognitive load could be decreased; in the meantime, their learning achievements could be improved owing to learning in a more efficient and effective way.

From the series of related studies conducted in the MAIL project, it is found that technologies are not the key or solution to cope with in-field learning problems. Without proper learning supports in the field, students might feel helpless, frustrated and aimless, and hence their learning attitudes or motivations could be affected. Moreover, their cognitive load can be high owing to the strategies or tools used to link what they have learned and observed together, and hence their learning achievements could be disappointing. On the other hand, from the experimental results, it is also suggested that grid-based tools are effective in helping students identify and differentiate a set of learning targets, while concept mapping tools are helpful to students in linking and organizing what they have observed in the field and have learned from the textbooks. That is, grid-based tools help students observe the learning targets with a "micro view," while concept mapping enables them to see things with a "global view." For example, if the aim of a context-aware activity of a language course is to help students learn to use vocabulary, phrases and sentence patterns related to the contexts, concept mapping could be useful; similarly, if the aim of a social studies course is to let students have a whole picture of a cultural asset, concept mapping is also a good choice. Nevertheless, if the aim is to foster students’ ability of identifying or differentiating the artifacts from different historical periods, grid-based Mindtools are good candidates.

Therefore, when designing Mindtool-based u-learning activities for different subjects, the following procedure is suggested:

1. Review the nature of the learning content to see if the aim of the subject unit is relevant to identifying and differentiating a set of learning targets based on their features, or organizing the relevant concepts by finding the relationships between them. Accordingly, the Mindtools to be employed in the learning activity can be determined.

2. Design the learning tasks based on the aims of the activity. For the learning activities with grid-based Mindtools, both problem-based and inquiry-based learning tasks are recommended, depending on the level of learner control. For novice or younger learners, problem-based learning with instant feedback would be preferable; for experienced or older ones, inquiry-based learning with supplemental materials in e-libraries or on the web would be better. On the other hand, for the activities which incorporate concept mapping strategies, inquiry-based learning is recommended.

3. Determine the technologies used in the learning activities. It is suggested that at least mobile and wireless communication technologies are required, while sensing technologies are optional. One of the reasons for adopting sensing technologies is to provide students with learning tasks, learning supports or supplementary materials at the right place and at the right time, which not only reduces the load of students in searching for the information, but also makes the learning process more efficient.

4. Determine the way to measure the learning performance of students and provide feedback to them. For the activities using grid-based Mindtools with the problem-based learning approach, automatic scoring and instant
feedback can be provided. For inquiry-based learning, scoring rubrics need to be defined by teachers in advance for measuring students’ findings, dialogs, learning sheets, and learning behaviors; moreover, a knowledge sharing mechanism could be helpful to the students in making reflections.

Conclusions and future work

In this paper, an advanced u-learning project entitled “MAIL” with various dimensions of research design, issues and contributions, has been presented. The integrated project has aimed to develop Mindtool-assisted u-learning environments to improve the in-field learning performance of students. A total of 73 u-learning activity-based studies have been conducted in the past five years to investigate the effectiveness of the Mindtool-assisted u-learning approach in terms of improving students’ learning achievements, learning motivation, learning attitudes, and technology acceptance degrees, among other aspects. The experimental results show that the research-proven approach with multiple practices in various settings is both promising and appealing.

In terms of LT innovation, the findings of the MAIL project provide several new contributions to the field of mobile and ubiquitous learning. It has been demonstrated that simply adopting new technologies for students to learn in a real-world learning environment is not good enough. What is more important is for us to design appropriate pedagogical strategies as Mindtools for providing better support to students in an authentic in-field ubiquitous learning environment with procedural and contextual components. It is expected that the accomplishments of the MAIL project can provide research-proven LT know-how of Mindtool-assisted ubiquitous learning as well as references for those researchers and practitioners who are interested in conducting in-field activities with instant supports from technologies.

The various designs and experiments described in this paper can serve as a good reference model for practitioners and researchers who are interested in this emerging field of LT. This paper also reveals several essential future research topics, which are summarized as follows:

- Track students’ learning activity logs as a way to support learning analytics studies in mobile and ubiquitous learning environments. For example, it would be interesting to analyze the students’ learning patterns and investigate the relationships between the patterns and their learning performance. Moreover, it is important to further examine the effects of the Mindtool-based u-learning on students’ higher order thinking based on the learning logs of students’ in-field learning behaviors.

- Provide instant and personalized learning supports based on the learning logs and profiles of individual students. Although Mindtools are theoretically helpful to students in constructing and organizing knowledge, students might find it difficult to effectively use Mindtools during the in-field learning activities. For example, some students might have difficulty in developing concept maps without appropriate assistance. That is, while learning with Mindtools in the field, students might require instant and personalized supports. Therefore, it is important to provide instant learning supports by analyzing the learning logs and profiles to identify their problems and needs in the field.

- Develop seamless learning environments by integrating front-end in-field learning experiences with the backend support of Learning Management Systems (LMS) by using the cloud technology so as to apply versatile Mindtools in more courses. In addition to the concept map and grid-based Mindtools developed in this paper, other Mindtools reported by Jonassen (2004) could be included for helping students learn in more effective and constructive ways. For example, spreadsheets could be an effective Mindtool for helping students infer the relationships between variables in Mathematics and Physics courses; database management systems could be Mindtools that engage students in analytical tasks; simulation software could be helpful to students in associating abstract theories with real-world scenarios. Therefore, it is worth investigating the possibility and effectiveness of applying those Mindtools to different u-learning activities.

These cutting-edge research topics and issues are worth our efforts to shed more light on this ever-changing, promising field of context-aware ubiquitous learning in Learning Technology. Recently, the Ministry of Education in Taiwan has initiated a large-scale program for applying mobile and ubiquitous strategies and tools in all levels of schools. In 2012, one hundred schools were selected as demonstration sites, and the number of schools participating in the program will be increased each year. In those schools, each student in the selected classes is equipped with a
mobile device. In each city or county, a cloud-based educational service system has been established to support the anywhere and anytime learning. Moreover, a series of training programs has been proposed to train teachers in how to design in-class and in-field activities with the strategies and tools developed based on the experiences and findings of MAIL and some other studies. It is expected that mobile and ubiquitous learning will become a regular form of learning in the coming five years in Taiwan.

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References


