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Perceptions of learning effectiveness in M-learning: scale development and student awareness

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Abstract

The purpose of this study is to develop a multi-dimensional scale to measure students' awareness of key competencies for M-learning and to test its reliability and validity. The Key Competencies of Mobile Learning Scale (KCMLS) was determined via confirmatory factor analysis to have four dimensions: team collaboration, creative thinking, critical thinking and problem solving, and communication. The research subjects are 815 students from the elementary school that participate in M-learning programme in Taiwan. The research results show that students have better self-awareness in team collaboration and creative thinking, but have worse self-awareness in critical thinking and problem solving. This study also found that there was no significant difference between genders in the KCMLS, but students who study in the schools that committed in M-learning longer have higher awareness in all dimensions than students who study in the schools that committed to M-learning in fewer years.

Keywords

communication, creative thinking, critical thinking and problem solving, M-learning, team collaboration.

Introduction

Using mobile devices in learning activities has been popular that it provided diverse channels in which students can learn, communicate and collaborate (Chu, Hwang, & Tsai, 2010; Gikas & Grant, 2013; Kim & Smith, 2015), so creating an M-learning environment has become an important trend (Crompton, Olszewski, & Bielefeldt, 2016; Dennen & Hao, 2014; Lai, Hwang, Liang, & Tsai, 2016). The value of mobile devices as a teaching tool has been proven by many positive research results (Echeverría et al., 2011), and creating a large scale M-learning environment was found that an M-learning environment not only is feasible and

usable but also satisfies society's needs and challenges (Grönlund & Islam, 2010). However, the efficacy of M-learning environment in students' competencies requires further study.

Key competencies are students' learning and living capabilities in the modern social, economic and cultural environment (Hattam & Smyth, 1998; Thompson & Craft, 2001), and sustainable education is viewed as learning the key competencies of individuals to help society make progress (Rieckmann, 2013). Therefore, developing students' key competencies has been the focus of recent educational reform. The education policy of many countries uses key competencies as the basis for education reform and development (Soparat, Arnold, & Klaysom, 2015; Takayama, 2013).

There have not a consensus on the most important key competencies in M-learning (Rieckmann, 2012). Prior literature has point out the relationship between team collaboration, creative thinking, critical thinking and

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problem solving, communication and M-learning (Lai & Hwang, 2014; McQuiggan, McQuiggan, Sabourin, & Kosturko, 2015). Collaboration is important, and courses designed around mobile devices can effectively improve students' collaboration capacity (Lee *et al.*, 2016). Chang, Chien, Yu, Lin, and Chen (2016) demonstrated that an M-learning environment can effectively improve students' creativity ability. Sánchez and Olivares (2011) noted that using mobile devices in learning activities can effectively improve the planned execution aspect of students' problem solving ability. M-learning also improved students' critical thinking (Lee *et al.*, 2016). Dwyer, Hogan, and Stewart (2012) found that an e-learning environment can effectively improve critical thinking. Lan, Tsai, Yang, and Hung (2012) found that compared with e-learning, when students use mobile devices for communication, they will be more involved, think more, be more responsive and share more information.

The purpose of this study is to re-examine the potential dimensions of students' M-learning, construct a Key Competencies of Mobile Learning Scale (KCMLS) and verify the validity of the KCMLS. The KCMLS is a hypothetical model that is used to explain students' self-awareness of effectiveness of M-learning performance, and this model must be verified. Previous study verified that the amount of time participating in mobile learning and learning strategy can significantly improve students' communication ability, complex problem solving ability and creativity (Lai & Hwang, 2014). There have not been any studies on whether or not the time schools participate in mobile learning projects have an effect on students' key competencies, which is also an important issue.

This study will explore the following four questions:

1. Could a KCMLS model be constructed and validated through CFA?
2. What is elementary students' self-awareness of key competencies?
3. Does the gender of elementary students make any difference in their self-awareness regarding the key competencies?
4. Does the time duration of school attending M-learning programme make any difference regarding students' self-awareness effectiveness of the key competencies?

Literature review

Learning effectiveness dimension of e-learning

Different aspects of learning outcome or key competencies are developed for e-learning. Thompson and Craft (2001) proposed 14 key competencies of students in e-learning environment. Tsai (2009) defined e-learning output as perceived skill, affection and self-regulation from a meta-cognitive perspective. Rieckmann (2012) divided 12 key competencies of e-learning environment into the dimensions such as systemic thinking, anticipatory thinking and critical thinking. Soparat *et al.* (2015) analysed e-learning outcome of students from the perspective of key competencies to see if students improved their communication capability, thinking capability, problem solving capability, life skills capability and technological application capability. However, e-learning environment covers a broad scope, in which M-learning environment is characterized by convenience, flexibility of use and mobility (Fulantelli, Taibi, & Arrigo, 2015; Hsu & Ho, 2012). Hence, the application of M-learning is quite different from e-learning in an educational setting, and key competencies of students in an M-learning environment require further study.

To understand the effectiveness of M-learning environment, it is necessary to know the M-learning outcomes mentioned in previous studies. Lai and Hwang (2014) analysed students' awareness of the M-learning outcomes such as collaboration capacity, creativity, complex problem solving and communication. McQuiggan *et al.* (2015) stated that M-learning can improve students' high-level thinking skills, for example, collaboration, creativity and communication skills. It indicated that M-learning is closely related to the skills such as collaboration, creativity, problem solving and communication.

Team collaboration

Team collaboration is a skill that includes valuing every member of the team, being able to collaborate with other teams, maintaining flexible work ethics and respecting the team's schedule when there is a conflict with a personal schedule (McQuiggan *et al.*, 2015). Collaboration occurs according to the interaction and interdependence between students when learning (Engellant, Guzik, & Williams, 2014) and team

collaboration is the ability to work with team members for common objectives and improves the understanding of the characteristics and abilities of the team members (Gevers, Rispen, & Li, 2016).

Many studies have proven that M-learning benefits team collaboration (Lee et al., 2016; Sánchez & Olivares, 2011). Echeverría et al. (2011) found that students' collaboration ability significantly increased with the use of both Personal Digital Assistant (PDA) and handheld computers. Koutromanosa and Avraamidou (2014) further analysed literature concerning M-learning and found effectively improved students' collaboration in both in formal and informal learning environments.

Creative thinking skill

Creativity was defined as a specific internal process of an individual or social product (Csikszentmihalyi, 1988). The activity of creativity involves creative thinking (Fumoto, Robson, Greenfield, & Hargreaves, 2012), and it can be taught and every student should be encouraged to have creative thinking (McQuiggan et al., 2015).

Mobile devices provide an excellent external environment for the expression of creativity (McQuiggan et al., 2015). Chang et al. (2016) created a cloud-based M-learning environment and found that students were more perceptive of innovative elements, and it allows them to achieve better creative performance. Chang, Pan, and Huang (2013) incorporated smart phone as a mobile platform into innovative learning activities and finding that the use of mobile devices for learning allowed students to have a better creative thinking.

Critical thinking and problem solving

Critical thinking is the decision-making process for purposeful self-adjustments (Jou & Wang, 2015). It involves observation, comparison, explanation and prediction (Rodd, 1999), and it further promotes problem solving skill. Courses designed around mobile devices can effectively increase students' critical thinking capacity and problem solving (Lee et al., 2016; Sánchez & Olivares, 2011). Newton (2013) designed a game-based teaching activity in an M-learning environment and used a mobile platform to teach the critical thinking process, and the result showed an effective improvement in students' critical thinking. Vuong, Siu, and Hui (2010)

incorporated handwriting technology into math courses and found that it effectively improved students' problem solving ability. Yen and Lee (2011) further found that students' problem solving performance significantly improved when they are able to more efficiently use mobile devices for learning.

Communication skill

Communication includes the abilities that accepting and understanding external information, integrating different resources and orally expressing thoughts (McQuiggan et al., 2015), and using mobile technology to improve students' communication is becoming a part of student life (Zhang et al., 2010).

Using the social media function of mobile devices for learning is significantly correlated to interpersonal relations and online social support and provides great benefits (Sobaih, Moustafa, Ghandforoush, & Khan, 2016; Tang, Chen, Yang, Chung, & Le, 2016). Amiel, Simon, Merin, and Ziv (2016) found that mobile devices allow students to learn in a simulated situation, and results show that their team collaboration and communication skill both significantly improved. Biddix, Chung, and Park (2016) found that American students communicated significantly more and better when using mobile devices to chat or ask questions during class.

Method

Methods and assumptions

This study develops a scale for the awareness of key competencies of students in an M-learning environment using a construct validity approach and designs the questionnaire through the following procedures: first, factors of the conceptual model of key competencies were obtained from the literature review and provided the basis for developing the questionnaire. After testing the questionnaires expert validity with two experts, CFA is performed for model verification. Because the EFA results magnify chance variation, using the EFA results as normative analysis results of the CFA model will aggravate the issue (Kline, 2005). Therefore, this study uses the CFA for validity analysis for demonstrating the validity of the KCMLS. Next, this study analyses differences in students' awareness of

key competencies with respect to sex and time the school participated in the M-learning project. Assumptions of this study are as follows:

1. Gender made statistical differences of students' awareness of key competencies.
2. The period a school has participated in the M-learning project made statistical differences of students' awareness of key competencies.

Contexts and participants

The participants of this study are third to sixth graders in Taiwan. The school they attend was interested in M-learning and participated in the M-learning programme from less than 1 year to over 4 years. This study collected 893 questionnaires, of which 815 were effective samples, giving an effective response rate of 91.3%. The questionnaire items are measured on a five-point Likert scale. Subjects responded to the items by choosing 1 (strongly disagree) to 5 (strongly agree).

The questionnaire included basic items, for example, gender, student grade and school name. Because students did not know how long their school had provided an M-learning environment, this variable was categorized by the researcher based on the year that the school filed its application. There have 471 men (57.8%) and 344 women (42.2%) of respondents. Regarding the number of years that the schools participated in the M-learning programme, 297 (36.4%) participants' school participated in an M-learning programme for less than 1 year, whereas 181 (22.2%) participated for 2 to 4 years and 337 (41.3%) participated for over 5 years.

This study collects and analyses data of students in elementary schools that participated in the experiment implemented M-learning course and created an M-learning environment using a table PC, an Interactive Response System (IRS) system and M-learning platforms, allowing students to learn with their mobile devices. The schools offer diverse courses and teaching activities with rich contents under the M-learning project and have authority to decide on the using way and time in learning with mobile devices, on average, the courses are using mobile devices at least once per week.

The mobile devices were used for interactions and discussions, viewing various diagrams, collecting data, drawing diagrams to improve students' collaborative

learning ability, creative thinking, critical thinking, problem solving and communication ability.

Tool

The KCMLS aim to assess students' awareness of the key competencies, consisting of dimensions from the four components, as follows: (1) team collaboration, (2) creative thinking skill, (3) critical thinking and problem solving and (4) communication (see Appendix 1 for statements regarding each dimension). The concept of 'team collaboration' centred on learners' interaction with learning through responding, commenting and discussing to reach their learning objectives, the items were referred to Yamamoto et al. (2014). The concept of 'creative thinking' centred on the learners' originality, flexibility, fluency and elaboration of their learning, and the items were referred to Kaufman (2012) and Sen, Acar, and Cetinkaya (2014). The concept of 'critical thinking and problem solving' centred on the learners' ability to demonstrate a proper problem solving method that used a high-level thinking process, and the items were referred to Gok (2011), and Yuan, Liao, Wang, and Chou (2014). The final concept is 'communication', which described the learners' delivery and receiving of meaning in the learning context, and the items were referred to Chang et al. (2011). A total of 69 items were collected as the item pool for the KCMLS. To conduct the initial model of the KCMLS, two college teachers who were committed to learning through technology were invited as experts to review those items. After two meetings of the experts, 22 of the 69 items were selected for the initial model of the KCMLS.

Results

Model testing results

This study uses CFA to validate the hypothesis model. Table 1 shows data from the initial measurement model, and the results indicate a relatively poor fit. The data generated from AMOS indicate that the standardized residuals of many items were higher than 3.0, those items with excessive standardized residuals were removed, and the measurement model was revalidated. The results show that 14 of the 22 items in the initial measurement model were analysed. Each dimension includes at least

Table 1. Model Fit Measurement Statistics

Model	Initial	Revised	Model-fit criterion
X2	1199.804	126.044	Compares the obtained X2 value with the tabled value for a given df
df	205	73	
X2/df	5.853	1.727	
RMSEA	0.077	0.030	<0.05: good fit 0.05 ~ 0.08: acceptable fit
SRMR	0.0592	0.0264	<0.05: good model fit
GFI	0.865	0.978	>0.95: good fit
CFI	0.833	0.988	>0.95: good fit

three items, in which the content validity was adequate for all items.

The chi-square score for the revised model was 126.04 ($p < 0.001$), showing a relatively poor goodness of fit. However, the chi-square is easily influenced by the sample size (Kline, 2011), the sample size of this study was relatively large ($n = 815$), it was necessary to use other goodness of fit indicators for further discussion. The ratio of the chi-square to the degrees of freedom (χ^2/df) of revised model is 1.73, it is less than 0.001 when calculated into a p -value, indicating a very good fit of the

hypothetical model and sample data (Kline, 2011). Table 1 shows other goodness of fit indicators for the revised model: RMSEA = 0.030, SRMR = 0.026, GFI = 0.98 and CFI = 0.99. According to Kline (2011) and Schumacker and Lomax (2010), the revised measurement model exhibits a good fit and is in line with the psychometric properties of the KCMLS. As shown in Figure 1, the loading of each item corresponding to its dimension is between 0.69 and 0.82 and reaches a level of significance. Hence, the validity of the KCMLS is supported by the statistical data.

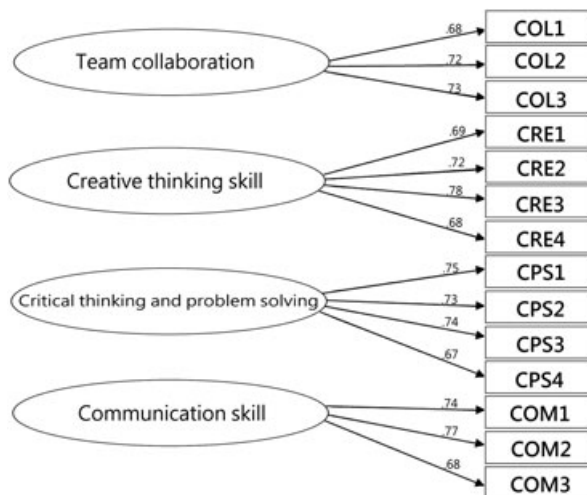


Figure 1 The Results of Confirmatory Factor Analysis: The Pattern Coefficients for the Four Key Competencies in the KCMLS. COL, team collaboration; CRE, creative thinking; CPS, critical thinking and problem solving; COM, communication

Validity and reliability

This study uses composite reliability as the standard for evaluating the reliability of the KCMLS. Related studies indicated that when composite reliability is higher than 0.7, the model’s reliability is acceptable (Fornel & Larcker, 1981). Table 2 shows that the composite reliability of all four dimensions is acceptable.

The values of the average variance extracted (AVE) for the four dimensions of the KCMLS are between 0.505 and 0.534, all of which are above 0.5, providing substantial evidence regarding the convergent validity of the four dimensions (Table 2). The evidence of the discriminate validity is that the square roots of the AVE dimensions were all at least 0.5 (Fornel & Larcker, 1981) and were higher than between any dimension and the other dimensions in the model. Table 3 shows the correlation between the four dimensions. The

Table 2. The Reliability, AVE and CR of the Confirmatory Factor Analysis

Measures	Items	Composite reliability	Average variance extracted (AVE)
Team collaboration	3	0.753	0.505
Creative thinking skill	4	0.810	0.516
Critical thinking and problem solving	4	0.814	0.523
Communication skill	3	0.774	0.534

Table 3. The Correlations among Constructs (the Square Root of AVE in the Diagonal)

	Team collaboration	Creative thinking skill	Critical thinking and problem solving	Communication skill
Team collaboration	0.711			
Creative thinking skill	0.579	0.718		
Critical thinking and problem solving	0.567	0.614	0.723	
Communication skill	0.589	0.551	0.678	0.731

diagonal values are the square root of AVE, showing that all of the dimensions of the KCMLS satisfy the condition.

Differences among students' awareness of the four key competencies on the KCMLS

Table 4 shows that the mean score of the four dimensions is between 3.66 and 4.20, indicating mid-level to high-level self-awareness of students in key competencies in M-learning environment. To further verify the differences between the four dimensions of the KCMLS, this study uses multivariate, repeated one-way analysis of variance to compare the mean scores of the four dimensions; the higher mean score indicates that students believed that they performed better in the key competency. Comparing the mean scores of the four dimensions shows the level of perceptions by students

in the four key competencies. The results showed that Hotelling's Trace reached the level of significance ($F = 85.243, p < 0.001$). A post hoc test further showed that the mean score of team collaboration was greater than the other three factors' mean scores; that the mean score of creative thinking was greater than the mean scores of communication and critical thinking and problem solving; and that the mean score of factor communication was greater than the mean score of critical thinking and problem solving.

Gender differences in the four key competencies

This study analyses differences between genders in each dimension of the KCMLS using multivariate analysis of variance, and the results showed that the differences between genders in all dimension of the KCMLS did not reach the level of significance (Table 5).

Table 4. The Results of Multivariate One-Way ANOVA and the Post Hoc Test

Dimension	Mean	SD	F value (Hotelling's trace)	Summary of the significant differences in the paired samples in the post hoc test
Team collaboration	4.20	0.771	64.552***	COL > CRE > COM > CPS
Creative thinking skill	3.98	0.905		
Critical thinking and problem solving	3.66	0.885		
Communication skill	3.87	0.838		

*** $p < .001$.

Table 5. The Descriptive Statistics and F Test of Gender on the Dimensions of Four Key Competencies (Male, 471; Female, 344)

	Gender				F	P	Partial eta squared
	Male		Female				
	M	SD	M	SD			
Team collaboration	4.244	0.783	4.320	0.738	1.945	0.164	0.002
Creative thinking skill	4.072	0.813	4.050	0.798	0.148	0.700	0.000
Critical thinking and problem solving	3.876	0.902	3.399	0.850	1.517	0.214	0.002
Communication skill	4.001	0.833	4.048	0.795	0.631	0.424	0.001

The school's participation duration differences in the four key competencies

This study further analysed the correlation between the length of time a school implement M-learning programme and the students' awareness in the dimensions of the KCMLS. This study divided schools into three groups based on the time they participated in the M-learning programme: (1) less than 1 year, (2) 2 to 4 years and (3) more than 5 years; 36.4% of the students were in schools that participated in the M-learning programme for less than 1 year, 22.2% of the students were in schools that participated in the M-learning programme for 2 to 4 years, and 41.3% of the students were in schools that participated in the M-learning programme for more than 5 years.

The multivariate analysis of variance results showed that the duration a school participated in M-learning programme made significant differences in the KCMLS ($F = 3.973$, $p < 0.000$; Wilks' Lambda = 0.962; partial eta squared = 0.019). Table 6 shows that the duration a school participated in M-learning made significant differences in the mean scores of team collaboration ($F = 12.62$, $p < 0.001$), creative thinking ($F = 3.25$, $p < 0.05$), communication ($F = 4.73$, $p < 0.01$) and critical thinking and problem solving ($F = 5.76$, $p < 0.01$). A multiple-comparison analysis revealed a further result, and Scheffe's post hoc analysis was used. The result displayed that participation in M-learning for 2 to 4 years ($p < 0.01$) and more than 5 years ($p < 0.001$) rated team collaboration significantly higher than participation in M-learning for less than 1 year. Participation in M-learning for more than 5 years scored higher than participation in M-learning for less than 1 year with respect to creative thinking ($p < 0.05$) and

critical thinking and problem solving ($p < 0.01$). In addition, participation in M-learning for 2 to 4 years ($p < 0.05$) and more than 5 years ($p < 0.01$) rated communication significantly higher than participation in M-learning for less than 1 year.

Discussion

Dimensions of elementary students' key competencies

This study constructs a conceptual framework for understanding M-learning outcome and analyses the reliability and validity of the KCMLS, to further research in the field.

The CFA results supported the four dimensions of the KCMLS: team collaboration, creative thinking, critical thinking and problem solving, and communication. All of the constructs displayed sufficient reliability and discriminate validity. The four dimensions of the KCMLS all had a good composite reliability higher than 0.7 (Fornel & Larcker, 1981). All of the factor loadings reached the level of significance ($p < 0.001$), expressing that each item represented the corresponding factors and that all of the constructs share more variance with their indicators than with other constructs. Therefore, this study found that the KCMLS was very valuable in measuring students' awareness of key competencies in M-learning.

The key components were important to reveal the learners' awareness of effectiveness in an M-learning environment. The KCMLS instrument can be characterized as measuring the self-efficacy of general ability of a student beyond the subjects. The instrument developed in this study has adequate virtue to withstand further research in the area.

Table 6. The Descriptive Statistics and the F Test of M-learning Attendance Years on the Dimensions of Four Key Competencies

	Mean (SD) of M-learning attendance years			F	Partial eta squared	Post hoc analysis
	Less than 1 year	2–4 years	More than 5 years			
Team collaboration	4.10 (0.83)	4.34 (0.78)	4.40 (0.66)	12.62 ***	0.030	3,2 > 1
Creative thinking skill	4.01 (0.85)	4.05 (0.90)	4.14 (0.79)	2.12*	0.008	3 > 1
Critical thinking and problem solving	3.89 (0.84)	4.10 (0.79)	4.09 (0.80)	5.76**	0.012	3 > 1
Communication skill	3.74 (0.89)	3.82 (0.94)	3.95 (0.82)	4.74**	0.014	3,2 > 1

* $p < .05$.

** $p < .01$.

*** $p < .001$

Students' scores of the four key competencies on the KCMLS

Research problem 2 focuses on the awareness of effectiveness of elementary school students' key competencies in M-learning. The students' mean scores for the four dimensions were all higher than 3 and were between 3.66 and 4.20 on a five-point Likert scale, in which students had the highest mean score in the dimension of team collaboration, followed by creative thinking and communication, with the lowest mean score in the dimension of critical thinking and problem solving.

This result indicates that pupils whose schools participating in the M-learning programme are very confident in their team collaboration. There are a relatively large number of classes of elementary school in Taiwan, and one class can have up to 34 students. Hence, collaborative learning is highly valued by for pupils to fully participate in class. The results of this study show that the awareness of team collaboration among Taiwanese students is already at a high level. The sampled students also demonstrated confidences in their creative thinking. This is supported by the finding from McQuiggan et al. (2015) that creative thinking may play an important role in a mobile-learning activity. Karakaya and Demirkan (2015) stated that collaborative learning activities in a digital environment can effectively improve students' creativity; it shows a correlation between team collaboration and creativity.

In addition, communication of sampled students' awareness in general seems to be somewhat confident. The learners' interactions occur between not only students but also students and instructors in various ways. The communication technologies of mobile devices allow students to learn at any time and in any place and also combine resources of the real world and the digital world. However, the results may be disappointing if there are no effective tools to help students learn (Hwang, Wub, & Kec, 2011). Therefore, developing a platform to aid communication and interaction has become an indispensable element in M-learning. Liaw, Hatala, and Huang (2010) noted that when mobile devices are combined with a suitable interaction platform, it creates an online environment with the greatest amount of interaction and communication. In the digital age, students can use different communication methods on diverse communication channels, for example, social media,

forums and chatrooms (Fumoto, Robson, Greenfield, & Hargreaves, 2012; Yu, 2011; Yücel & Usluel, 2016).

In this study's four key component dimensions, the mean scores of students' self-ratings were significantly lower for critical thinking and problem solving than for the other dimensions. The context of teaching has an important effect on students' critical thinking (Christie, Beames, & Higgins, 2016). The meaning of education in china culture is 'administering by the superior and followed by the subordinate' and 'bringing up children to do good', which is a teacher-centric view of teaching in traditional Eastern culture, while students' responsibility is to follow the instructions (Chen & Wang, 2012). Traditional Eastern culture attaches less importance to critical thinking, and students often lack problem solving abilities when learning in this cultural context (Tsai, 2010). Taiwan's method of education has returned to the classics, in hopes of cultivating students with a learning attitude that meets society's expectations. Students' awareness, however, shows that critical thinking requires further practice in education. Critical thinking and problem solving are abilities that involve higher level thinking (McQuiggan et al., 2015). Higher level critical thinking and problem solving skills are key competencies that students require when facing problems in life, so it is important that learners have the ability to develop these critical thinking and problem solving skills. Yu (2011) indicated that the application of collaborative learning strategies and a peer-assessment system in technology-assisted learning can effectively elevate their thinking ability. Furthermore, elementary school education in Taiwan emphasizes textbook-based teaching, and even though problem-based learning for solving actual problems in life is also valued, teaching results are not ideal in an atmosphere of teaching to pass tests. Linking school learning to students' life experiences and further developing critical thinking and problem solving skills is an issue worth further discussion in Taiwan's education.

Gender and grade differences in the elementary students' key competencies

The research results indicate that male and female students have a similar awareness of learning effectiveness in the key competencies. They showed similar attitudes and behaviour regarding their

collaborative ability, creative thinking, communication, and critical thinking and problem solving in learning activities. This result is consistent with previous studies (Felnhofer et al., 2014) in that there are no significant differences between the capabilities of male and female students, who showed similar learning results. However, some studies have indicated significant differences between specific capabilities of male and female students, such as creativity (Bart, Hokanson, Sahin, & Abdelsamea, 2015). In addition, even though there was no significant difference in the self-awareness of team collaboration, there were differences in learning strategies between genders in collaborative learning environment (Lee, 2015).

The amount of time schools participated in M-learning programme seems to make a difference in students' awareness of learning effectiveness. Ye, Ye, and Lin (2013) stated that students who used e-learning for a long period of time had better e-learning knowledge management, self-regulated learning and ability to make sense than students who used e-learning for a short period of time. In this study, the research results indicate that students in schools that participated in the M-learning programme for a long time had better awareness of learning effectiveness in all dimensions compared with students in schools that participated in M-learning programme for less than 1 year. Lai et al. (2016) found that in the M-learning environment, the students regarded more about the learning content, while teacher inclined to focus more on the technical issues. Teachers in schools that have participated in an M-learning project for a longer period of time will encounter relatively less technical difficulties and will be able to focus more on the variety and usefulness of learning contents, which will enhance students' awareness of key competencies. This research result shows the importance of the time that schools participate in M-learning programme regarding students' team collaboration, creative thinking, critical thinking and problem solving, and communication. Many studies have noted the contribution of M-learning to students' learning outcome, and students' participation in e-learning significantly improved their ability to communicate ideas and solve problems (Soparat et al., 2015). Rau, Gao, and Wu (2008) indicated that communication on mobile devices was effectively linked to learning subjects and did not put pressure on students compared with speaking during

public occasions. Hence, students were able to focus on practicing communication skills in M-learning, which improved their communication. Furthermore, mobile devices provide students with a personal space where they are safe from public embarrassment and are thus less afraid to make mistakes when attempting to solve problems (McQuiggan et al., 2015), which further develops their problem solving ability. Lai and Hwang (2014) indicated that students who spent more time on M-learning activities had better communication concepts, complex problem solving abilities and creativity, but there was no significant difference in their awareness of collaboration. This study further verified that the length of time schools participate in a M-learning programme results in a significant difference in students awareness of their collaborative ability, creative thinking, communication, and critical thinking and problem solving. School learning constitutes an important part of the students' learning activities. This study provides evidence of the correlation between the time schools participated in the M-learning programme and the awareness of learning effectiveness of students.

Conclusion

This study proposed key competencies of mobile learning environment, constructed an instrument to measure students' awareness of key competencies and analysed students' differences of perception upon those competencies in sexes and the period of time the school participated in M-learning. The results of this study show that students of schools participating in the M-learning programme have a positive perception of their key competencies for M-learning, namely, team collaboration, creative thinking, critical thinking and problem solving, and communication. Students from schools that participated in the M-learning programme for a longer period of time performed significantly better awareness in the key competencies than students from schools that participated in the M-learning programme for a shorter period of time. It is noteworthy that the effectiveness of M-learning is not only affected by participation time, but many other factors that are worth exploring. This study constructs a KCMLS and provides evidence supporting the key competencies of M-learning, which provides a basis for further research in the field of M-learning.

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Appendix

The KCMLS Dimensions and Items

Item no.	The dimensions/items
	Team collaboration
COL1	When divided into teams, every member is important to completing the tasks that are assigned.
COL2	I took part in the majority of the tasks assigned to the team.
COL3	Team activities taught me how to work with others.
	Creative thinking skill
CRE1	I often like to do new things.
CRE2	I like to visit new places.
CRE3	There are many things I like to attempt myself.
CRE4	I like to do new and original things.
	Critical thinking and problem solving
CPS1	When I encounter a problem, I will consider the problem from different perspectives to gain a more in-depth and thorough understanding.
CPS2	When I encounter a problem, I am usually able to think of a solution from different perspectives.
CPS3	I feel that the same standard must be used to compare solutions to determine if the approach adopted is suitable.
CPS4	When executing a solution fails, I will not give up and I will try other solutions.
	Communication skill
COM1	When talking to someone I know, I can use suitable words to express what I mean.
COM2	When talking to someone I know, the way I express things is clearly understood by others.
COM3	When I am listening to someone I know give a report or talk, I will listen attentively.