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Developing a survey for assessing preferences in constructivist context-aware ubiquitous learning environments

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Abstract This study developed a survey to explore students' preferences in constructivist context-aware ubiquitous learning environments. A constructivist context-aware ubiquitous learning (u-learning) environment survey (CULES) was developed, consisting of eight scales, including ease of use, continuity, relevance, adaptive content, multiple sources, timely guidance, student negotiation, and inquiry learning. The survey responses were gathered from 215 university students from five universities in Taiwan. The students all had actual experience of using u-learning systems in u-learning environments. Both exploratory and confirmatory factor analyses showed that the CULES had high reliability and validity. The structural model revealed that the provision of realistic and close-to-real-life information could enhance students' preferences for timely guidance, student negotiation, and inquiry-learning activities. In addition, the attainment of inquiry learning is quite challenging when designing u-learning activities, as it involves the enhancement of the other CULES scales.

Keywords constructivist epistemology, context awareness, student-centred learning, ubiquitous learning.

Study background

The developments in learning environments have encouraged the consideration of educational theory, and satisfying the individual differences and requirements of students to guide instructional design. Several studies have shown that students' individual differences play an essential role in learning, such as learning style, cognitive ability, and preferences (Wild & Quinn 1998; Sadler-Smith & Smith 2004; Graf *et al*. 2010). A learning style is defined as students' individual preferences that they may process information in a different way when carrying out a learning activity (Valley 1997). Because students' learning styles and preferences may be pre-determined, instructors should consider them rather than attempting to change them (Murray-Harvey 1994). However, some studies have pointed out that learning styles and preferences may be malleable and interact with learning environments (Reid 1987; Valley 1997). Hence, the design of learning environments should provide more flexible learning in respect of satisfying students' individual differences or fulfilling learners' preferences (Sadler-Smith & Smith 2004; Woo 2009).

Recently, students' individual differences and their preferences toward certain features of learning environments have drawn increasing attention from educators (Morgan *et al*. 2000; Ford & Chen 2001; Chuang & Tsai 2005). For example, Tsai and his colleagues (e.g. Wen

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et al. 2004; Chuang & Tsai 2005; Tsai & Chuang 2005; Tsai 2008) have developed a questionnaire called the constructivist Internet-based learning environments survey (CILES) and explored students' preferences for some important features of Internet-based learning environments. Their findings are viewed as a good reference for developing more favourable learning environments for students. They imply that if researchers have more information about students' individual perspectives in learning environments, they can develop more appropriate environments or systems (Tsai 2005). Therefore, the relationship between students' preferences and the features of learning environments could provide a framework for designing more appropriate learning environments.

Moreover, the issues of gender and grade difference in technology-based learning environments such as computer and Internet usage have been addressed in some previous studies (Barrett & Lally 1999; Tsai & Tsai 2010). These two background factors are found to be related to individuals' perspectives of technology usage in learning environments (Krendl & Broihier 1992; King *et al*. 2002). Some studies have revealed that males or younger students have more confidence and more positive attitudes than their counterparts in technology usage (Li & Kirkup 2007; Tsai *et al*. 2010). However, other studies have produced conflicting findings, such as older students having more confidence than their younger peers in technology usage (Loyd & Gressard 1984), and the gender gap not existing among elementary and secondary school students for technology usage (Volman *et al*. 2005). The role of gender and grade in technology usage in technology-based learning environments is still unclear. Passig and Levin (2000) indicated that well-designed learning interfaces increase interest in learning and could possibly be equally appreciated by both males and females. Therefore, when educators and system designers develop learning environments, there is a need to explore the role of preferences by gender and grade level in the features of learning environments.

In particular, the concept of the technology acceptance model (TAM), a well-known framework for understanding information technology adoption, was developed for predicting and explaining various human behaviours and intentions based on two personal beliefs: perceived usefulness (the belief that using the system will enhance learners' performance within an organizational context) and perceived ease of use (EU; the belief regarding to what degree using the system will be free of effort) (Davis *et al*. 1989; Venkatesh & Davis 2000; Pituch & Lee 2006). According to TAM theory, a student's performance of information technology usage is determined by his or her behavioural intention toward using information technology; his or her behavioural intention toward using information technology is jointly determined by his or her attitude toward using the information technology and the personal belief regarding perceived usefulness. And, his or her attitude toward using the information technology is fostered by his/her personal beliefs regarding perceived usefulness and perceived EU. These two personal beliefs are related to students' views about information technology, and both of them guide students' intentions and behaviours, as well as their adoption of information technology. For example, some students' learning strategies may focus on increasing their personal belief regarding perceived EU, such as providing a better user interface (Davis *et al*. 1989). A similar idea was presented by Wen *et al*. (2004) that students' preferences regarding the cognitive and metacognitive features of Internet-based learning environments [such as engaging in inquiry learning (IL)] may focus on the technical and content features (such as EU). The technical–content aspect is perceived as students' perspectives about the information technology or content provided by the information technology, while the cognitive–metacognitive aspect is defined as how students engage in relevant cognitive and metacognitive activities (Lee & Tsai 2005). For example, students may engage in discussion and communication with peers if the learning environment provides an improved user interface. In sum, an individual's behavioural intentions in a learning environment are influenced by his or her usage beliefs.

Research about ubiquitous learning (u-learning)

In recent years, the technologies underlying ubiquitous computing, wireless communication, and context awareness (e.g. sensors) with mobile devices have created another innovative learning environment (Huang *et al*. 2008, 2010; Hung *et al*. 2010; Hwang & Chang 2011). This kind of learning environment has been called a context-aware u-learning environment (Hwang *et al*. 2011). In a u-learning environment, students can access digital materials or feedback through mobile devices in real situations. The two major characteristics of u-learning environments have been identified as including the support of seamless learning and an adjustable model of learning materials based on the detection of students' location, context, and individual needs (Ogata & Yano 2004; Hwang *et al*. 2008; Yang *et al*. 2008). For example, according to the learning process of each student, u-learning systems provide adaptive guidance for supporting them to learn in a complex-learning context (Hwang *et al*. 2009; Chu *et al*. 2010; Wu *et al*. in press).

Moreover, Chu *et al*. (2010) and Hwang *et al*. (2008) have indicated that the features of u-learning environments share some similar perspectives with the constructivist epistemology. For example, from the cognitive apprenticeship view, students can receive adaptive guidance from experts in u-learning environments (Wu *et al*. in press). Hence, u-learning environments can be utilized as essential components for constructivist environments. Honebein (1996) provided seven goals in the development of constructivist learning environments for designers: (1) provide experience with the knowledge construction process; (2) provide experience in and appreciation for multiple perspectives; (3) embed learning in realistic and relevant contexts; (4) encourage ownership and voice in the learning process; (5) embed learning in social experience; (6) encourage the use of multiple modes of representation; and (7) encourage self-awareness in the knowledge-construction process. U-learning environments support the first and second goals by providing various sorts of information for students to gather and achieve the educational objectives (El-Bishouty *et al*. 2007). The third goal is accomplished by all students who participate in the real situations (Hwang *et al*. 2008). By providing applicable feedback or guidance, students join in inquiry-learning activities; thus, u-learning environments support the fourth goal (Hwang *et al*. 2009). U-learning environments support the fifth goal by providing mobile devices to support face-to-face discussions (Yang 2006). The students must observe real things and access digital materials through mobile devices such as photographs; in this way, u-learning environments achieve the sixth goal (Joiner *et al*. 2006). Finally, by offering scaffolding, the students construct their answers and perform problem solving, and thus u-learning supports the seventh goal (Chu *et al*. 2010). In essence, if not used properly, u-learning environments may not be constructivist. But if carefully designed, they can fulfil the constructivist principles.

As the innovative instruction of u-learning has emerged in students' learning environments, and might play an important role in future learning environments, exploration of the main features and students' preferences in constructivist u-learning environments should be an essential research issue for educators and system designers. However, few studies have explored this issue. As university students have gradually become one of the major groups of u-learning users in Taiwan, investigating their preferences in constructivist u-learning environments is necessary for educational researchers and system designers. This study extends the assertion made by Davis *et al*. (1989) and Wen *et al*. (2004) that an individual's behavioural intentions in a learning environment (such as preference for cognitive activities) are influenced by his or her usage beliefs (such as EU). That is, this study examines this assertion particularly in the context of u-learning environments: students' preferences regarding the cognitive features of constructivist u-learning environments are guided by those in the technical and content features. In sum, the research questions of this study are

- What are the university students' preferences in constructivist u-learning environments?
- Using the structural equation modeling (SEM) analyses with linear structure relationships (LISREL), what are the relationships between students' preferences in the technical and content aspects (referred to as the technical–content aspect) of constructivist u-learning environments and those in the cognitive aspect?
- Is there any gender difference in the university students' preferences in constructivist u-learning environments?
- Is there any grade difference in the university students' preferences in constructivist u-learning environments?

Method

Participants

The participants of this study included 215 university students (consisting of 116 males and 99 females) from four universities in northern, central, and southern Taiwan. About a half of the participants were studying for an undergraduate degree ($n = 146$, 68%), while 32% ($n = 69$) were graduate students. The average age was 23. The majority of the sample ($n = 191$, 88.80%) were majoring in science and engineering, while the remaining students were majoring in humanities and social science. All of the participants responded to the constructivist u-learning environment survey (CULES) paper-and-pencil format in this study, and their backgrounds were also collected, such as age, gender, and grade level. Before responding to the CULES, all of the participants had actual experience of using mobile devices for more than 1 year and u-learning systems in u-learning environments for 3 months on average, such as in museums, butterfly ecology gardens, on the school campus and for learning the skills of operating or assembling electronic devices.

For example, a learning activity was implemented with the observation of butterfly ecology. Each student was equipped with a mobile device with a radio frequency identification (RFID) reader, and each ecology area had an RFID tag. When the students walked close to an ecology area, the reader would sense the code in the tag and send it to the learning system via wireless communications. Consequently, the learning system identified the location of the student and presented relevant learning tasks, supplementary materials or learning guidance accordingly.

Questionnaire exploring students' preferences in u-learning environments

To explore preferences in constructivist u-learning environments, this study developed an instrument: the CULES. The researchers consulted with two experts in the u-learning field regarding the initial framework and items of the CULES for face validity. The CULES integrated the main scales of the technical, content, and cognitive aspects from Tsai and his colleagues' CILES and CILES-revised (CILES-R) (Chuang & Tsai 2005; Tsai & Chuang 2005; Tsai 2008), revised the item descriptions according to the experts' suggestions, and added continuity (CO) and adaptive content (AC) scales that addressed the two special features of u-learning (including the support of seamless learning and the adjustable model of learning materials based on the detection of students' locations, contexts, and individual needs) (Ogata & Yano 2004; Hwang *et al*. 2008; Yang *et al*. 2008), as shown in Table 1. Therefore, the 'technical' aspect assessed the technical usage in the u-learning environments and consisted of the 'EU' and 'CO' scales. The 'content' aspect explored the features of the information contained in the u-learning environments and consisted of the 'relevance (RE)', 'AC', and 'multiple sources (MS)' scales. The 'cognitive' aspect investigated the cognitive and social interactions involved in the u-learning environments and consisted of the 'timely guidance (TG)', 'student negotiation (SN)', and 'IL' scales. In addition, these aspects also implied an ascending priority from the lower order (i.e. technical) to the higher order (i.e. cognitive) aspects.

Table 1 also shows that the scales of 'RE', 'MS', 'SN', and 'IL' were the same as those proposed by the original CILES and CILES-R, while the scales of 'CO' and 'AC' were newly added by this study, and the scales of 'EU' and 'TG' were revised from the original CILES and CILES-R scales of 'EU' and 'cognitive

Table 1. The aspects and scales considered in the development of CULES.

Aspect	Description	Scale
Technical	Measuring the technical usage in the u-learning environments.	Ease of use[1] Continuity[2]
Content	Investigating the features of the information included in the u-learning environments.	Relevance[3] Adaptive content[2] Multiple sources[3]
Cognitive	Exploring the cognitive activities and social interactions involved in the u-learning environments.	Timely guidance[1] Student negotiation[3] Inquiry learning[3]

[1]Revised CILES and CILES-R scale.
[2]New scale in this study (CULES).
[3]Original scale in CILES and CILES-R
CULES, constructivist context-aware ubiquitous learning environment survey; CILES, constructivist Internet-based learning environments survey.

apprenticeship', respectively. All of these scales were designed to explore students' preferences in the technical, content, and cognitive aspects of constructivist u-learning environments. Hence, the scales of 'reflective thinking' and 'epistemological awareness' in the metacognitive and epistemological aspects of the original CILES and CILES-R were omitted from the CULES. The scale of 'challenge' was also omitted because the concept of the scale was distributed to the CO, AC, and TG scales.

As a result, the initial version of the survey included 40 items (each scale included five items). The survey items were presented with bipolar strongly disagree/strongly agree statements in a five-point Likert scale from 1 = strongly disagree to 5 = strongly agree. That is, students with higher average scores on the CULES scales were more likely to hold stronger preferences for the specific features of the constructivist u-learning environments; on the contrary, those with lower average scores may express weaker preferences for the specific features of the constructivist u-learning environments. A detailed description of each scale is as follows:

- The *EU scale* measures perceptions of the extent to which students prefer that u-learning environments are easy to use. For example, 'when navigating u-learning environments, I prefer that they have user-friendly mobile devices'.
- The *CO scale* measures perceptions of the extent to which students prefer that u-learning environments help them continuously keep track of their own learning. For example, 'when navigating u-learning environments, I prefer that they can help me keep track of my learning'.
- The *RE scale* measures perceptions of the extent to which students prefer that u-learning environments are authentic and represent real-life situations. For example, 'when navigating u-learning environments, I prefer that they show how complex real-life environments are'.
- The *AC scale* measures perceptions of the extent to which students prefer to have opportunities to browse documents and information based on their requirements in u-learning environments. For example, 'when navigating u-learning environments, I prefer that they can provide information that I need, e.g. documents, images, and voice'.
- The *MS scale* measures perceptions of the extent to which students prefer that u-learning environments contain various relevant and multiple information sources. For example, 'when navigating u-learning environments, I prefer that they can discuss a learning topic through various perspectives'.
- The *TG scale* measures perceptions of the extent to which students prefer to have opportunities to receive TG for supporting them with the adaptive directions in the learning process at the right time and in the right place provided by u-learning environments. For example, 'when navigating u-learning environments, I prefer that they can provide useful feedback to guide learning at the right time and in the right place'.
- The *SN scale* measures perceptions of the extent to which students prefer to have opportunities to explain and talk about their ideas to other students in u-learning environments. For example, 'when navigating u-learning environments, I prefer that I can ask other students to explain their ideas'.
- The *IL scale* measures perceptions of the extent to which students prefer to have opportunities to be engaged in IL in u-learning environments. For example, 'when navigating u-learning environments, I prefer that I can find out answers to questions by investigation'.

Data analysis

This study involved three phases of data analysis procedures. In the first phase, it used an exploratory factor analysis method to clarify the structure of the students' preferences in constructivist u-learning environments. In addition, Kelloway (1998) indicated that more than 200 observations are suitable for the SEM analysis. Hence, in the second phase, this study viewed students' preferences in the technical–content aspect of u-learning environments as predictors to explain those for the cognitive aspect. Through the SEM analyses with LISREL, the relationships between the technical–content aspect and the cognitive aspect were explored. In the third phase, the roles of gender and grade level in the CULES responses were further explored.

There are varieties of fit indicators to assess the fit of a model. Kelloway (1998) indicated that chi-square is one of the most used indicators to assess the fit of a structural model. However, because it is very sensitive

Table 2. Rotated factor loadings and Cronbach's alpha values for the eight factors.

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Factor 1: Ease of use (EU) $\alpha = 0.91$								
EU1	0.75							
EU2	0.72							
EU3	0.71							
EU4	0.61							
Factor 2: Continuity (CO) $\alpha = 0.89$								
CO1		0.81						
CO2		0.71						
CO3		0.69						
CO4		0.58						
Factor 3: Relevance (RE) $\alpha = 0.88$								
RE1			0.65					
RE2			0.57					
RE3			0.55					
RE4			0.52					
Factor 4: Adaptive content (AC) $\alpha = 0.88$								
AC1				0.79				
AC2				0.68				
AC3				0.62				
AC4				0.61				
Factor 5: Multiple source (MS) $\alpha = 0.92$								
MS1					0.78			
MS2					0.71			
MS3					0.65			
MS4					0.44			
Factor 7: Timely guidance (TG) $\alpha = 0.87$								
TG1						0.70		
TG2						0.63		
TG3						0.58		
TG4						0.51		
Factor 6: Student negotiation (SN) $\alpha = 0.93$								
SN1							0.83	
SN2							0.80	
SN3							0.78	
SN4							0.76	
Factor 8: Inquiry learning (IL) $\alpha = 0.90$								
IL1								0.76
IL2								0.71
IL3								0.64
IL4								0.62
Eigenvalue	3.44	3.28	2.15	3.30	3.13	2.56	4.22	3.30
% of variance	10.75	10.26	6.72	10.30	9.77	7.99	13.20	10.33
Overall $\alpha = 0.97$, total variance explained is 79.33%								

to sample size, Jöreskog and Sörbom (1989) suggested that the degree of freedom can be applied as an adjusting standard regardless of whether the chi-square is large or small. Therefore, a chi-square per degree of freedom of below five shows good fit to the data. The recommended values of other types of different commonly used goodness-of-fit measures include root mean square error of approximation (RMSEA) below 0.08, root mean square residual (RMR) below 0.10, and the standard root mean square residual (SRMR) below 0.05, while one of the goodness-of-fit indexes (GFI), the adjusted goodness-of-fit index (AGFI), the normed fit index (NFI), the non-normed fit index (NNFI), and the comparative fit index with a value of over 0.90 indicates a good fit (Jöreskog & Sörbom 1993; Segars & Grover 1993; Tanaka 1993; Hoyle & Panter 1995; Selim 2003).

Results

Exploratory factor analysis for CULES

To clarify the structure of the students' preferences in u-learning environments, this study used exploratory factor analysis, principal component analysis with varimax rotation, to explore the factor structure among these items. An item within a factor was retained only when its loading was greater than 0.40 on the relevant factor and less than 0.40 on the non-relevant factor. As shown in Table 2, the results derived from the exploratory factor analysis method reveal eight factors among the items (to match the theoretical framework of CULES, the factors are not reported in the order of their extraction), accounting for 79.33% of the total variance explained.

Therefore, the initial 40 items were reduced to 32 items. The reliability (Cronbach's alpha) coefficients of the eight factors are 0.91, 0.89, 0.88, 0.88, 0.92, 0.87, 0.93, and 0.90, respectively; moreover, the overall alpha coefficient is 0.97. Accordingly, these scales proved to be highly reliable for measuring the students' preferences in constructivist u-learning environments. A full list of the items for the final version of CULES is presented in the Appendix.

Students' scores on the CULES scales

The students' average scores and standard deviations on the CULES scales are presented in Table 3. The students' highest scores were for the EU, AC, and RE scales. This implies that the students expect u-learning environments to be user-friendly, to provide realistic and close to real-life information, and to allow them to browse documents and information based on their requirements for advanced learning. The lowest average score on the CO scale implies that there were at least some students who did not intend to keep track continuously of their own learning in u-learning environments. In general, the findings were similar to those revealed by Chuang and Tsai (2005) and Tsai (2008) in that the students got high scores (all above 4 on a 1–5 Likert scale) on the responses of their preferences in

Table 3. Students' scores on the CULES scales.

Scale	Mean	SD	Range
Ease of use	4.39	0.69	1.0–5.0
Continuity	4.16	0.65	1.0–5.0
Relevance	4.29	0.65	1.0–5.0
Adaptive content	4.34	0.62	1.0–5.0
Multiple sources	4.23	0.70	1.0–5.0
Timely guidance	4.20	0.67	1.0–5.0
Student negotiation	4.17	0.75	1.0–5.0
Inquiry learning	4.23	0.71	1.0–5.0

CULES, constructivist context-aware ubiquitous learning environment survey.

constructivist learning environments. This implies that learners are more likely to hold constructivist-oriented views in u-learning environments.

Confirmatory factor analysis for CULES

Through the SEM analyses with LISREL, this study further confirmed the convergent and construct validity for each scale's items and the relationships between the technical–content and cognitive aspects of CULES. The results of the validity and reliability of the CULES are shown in Table 4. Convergent validity was established by all of the *t*-values showing statistical significance at the 0.05 level, indicating that all of the items within each scale were highly correlated with each other. In addition, the column of average variance extracted showed that the items for each scale accounted for between 64% and 77% of variance, and revealed construct validity. Moreover, the composite reliability coefficients also demonstrated the highly satisfactory reliability of the CULES. It was found that all of the coefficients were over 0.87, and the overall instrument reliability is 0.99. Accordingly, the CULES has validity and reliability for probing students' preferences in constructivist u-learning environments.

Furthermore, the five scales of the technical–content aspect (including EU, CO, RE, MS, and AC scales) relating to students' preferences in constructivist u-learning environments were utilized as predictor variables, and the three scales of the cognitive aspect (namely TG, SN, and IL scales) related to students' preferences in constructivist u-learning environments were utilized as the outcome variables for the analysis. The results of the fit measures for the CULES model (chi-square per degree

Table 4. The validity and reliability of CULES.

Scale	Item	Mean	SD	Factor loading	*t*-value	SMC	CR[1]	AVE
Ease of use	EU1	4.39	0.69	0.80	–	0.65	0.91	0.71
	EU2			0.82	13.62*	0.67		
	EU3			0.88	15.05*	0.77		
	EU4			0.87	14.86*	0.76		
Continuity	CO1	4.16	0.65	0.78	–	0.61	0.89	0.67
	CO2			0.85	13.41*	0.72		
	CO3			0.78	12.04*	0.60		
	CO4			0.85	13.38*	0.72		
Relevance	RE1	4.29	0.65	0.83	–	0.68	0.89	0.66
	RE2			0.85	15.08*	0.73		
	RE3			0.86	15.30*	0.74		
	RE4			0.70	11.45*	0.50		
Adaptive content	AC1	4.34	0.62	0.79	–	0.62	0.88	0.65
	AC2			0.86	13.85*	0.74		
	AC3			0.81	12.93*	0.66		
	AC4			0.75	11.58*	0.56		
Multiple sources	MS1	4.23	0.70	0.88	–	0.77	0.92	0.75
	MS2			0.88	18.13*	0.78		
	MS3			0.92	19.70*	0.84		
	MS4			0.79	14.66*	0.62		
Timely guidance	TG1	4.20	0.67	0.80	–	0.63	0.87	0.64
	TG2			0.81	13.07*	0.66		
	TG3			0.78	12.37*	0.60		
	TG4			0.80	12.81*	0.64		
Student negotiation	SN1	4.17	0.75	0.88	–	0.77	0.93	0.77
	SN2			0.86	17.22*	0.74		
	SN3			0.90	19.13*	0.82		
	SN4			0.88	18.12*	0.78		
Inquiry learning	IL1	4.23	0.71	0.88	–	0.77	0.90	0.71
	IL2			0.82	15.45*	0.67		
	IL3			0.83	15.77*	0.69		
	IL4			0.84	16.16*	0.70		

*$p < 0.05$.
[1]Instrument reliability: 0.99.
AC, adaptive content; AVE, average variance extracted; CO, continuity; CR, composite reliability; CULES, constructivist context-aware ubiquitous learning environment survey; EU, ease of use; IL, inquiry learning; MS, multiple sources; RE, relevance; SMC, squared multiple correlation; SN, student negotiation; TG, timely guidance.

of freedom = 1.76, RMSEA = 0.03, RMR = 0.06, SRMR = 0.02, GFI = 0.98, AGFI = 0.93, NFI = 0.99, and NNFI = 0.99) indicated a highly satisfactory fit and confirmed the CULES model's structure, as shown in Table 5.

The structural model and the summary of the maximum-likelihood parameter estimates, lambda, and the significance of the *t*-values are presented in Fig 1. The statistically significant relationships are shown with solid lines, and, for a cleaner display, other non-significant relationships are concealed.

From the technical–content aspect, EU, CO, and AC were only related to TG. MS was related to both TG and IL. RE was related to all three cognitive aspects, including TG, SN, and IL. Therefore, providing realistic and close-to-real-life information fosters the cognitive activities in u-learning environments.

In addition, from the cognitive aspect, EU, CO, RE, AC, and MS were the significant predictors for TG; RE was the only significant predictor for SN, and RE and MS were the significant predictors for IL. That is, TG

Table 5. Fit measures for the structural model of CULES.

Fit index	CULES	Recommended value
Chi-square (χ^2)	14.05	–
Degree of freedom (DF)	8	–
χ^2/DF	1.76	≤5
Root mean square error of approximation	0.03	≤0.08
Root mean square residual (RMR)	0.06	≤0.10
Standard RMR	0.02	≤0.05
Goodness of fit index	0.98	≥0.90
Adjusted goodness of fit index	0.93	≥0.90
Normed fit index	0.99	≥0.90
Non-normed fit index	0.99	≥0.90

CULES, constructivist context-aware ubiquitous learning environment survey.

was guided by all factors of the technical–content aspect (i.e. EU, CO, RE, AC, and MS). This implies that if TG is to be addressed, then the features of user-friendliness, keeping continuous track of students' learning, providing realistic information, browsing documents based on students' requirements, and offering various relevant information sources should be included. Although SN was only fostered by RE, for the interrelationships among the scales of the cognitive aspect, TG had a relationship with SN. Moreover, TG was positively guided by all of the technical–content aspects (i.e. EU, CO, RE, AC, and MS). Consequently, if SN is to be emphasized, not only the features from the cognitive aspects of TG should be acknowledged but also all of the factors from the technical–content aspect are necessary. Similarly, it is worth noting that if IL is to be addressed, not only the features from other cognitive aspects (i.e. TG and SN) should be fulfilled but also all of the factors from the technical–content aspect are required. This finding also implies that the attainment of IL is quite challenging when designing u-learning activities.

Gender differences on the CULES scales

This study compared the possible differences in the preferences in constructivist u-learning environments between male and female students. As shown in Table 6, the male and female students' scores on the CULES scales did not show significant differences, which imply that both male and female students tend to have similar preferences in constructivist u-learning environments.

The role of grade levels in CULES

This study also compared the possible differences in preferences in constructivist u-learning environments between the undergraduate ($n = 146$) and the graduate ($n = 69$) students. The t-test revealed that the graduate students had significantly higher preferences on the CO scale ($t = -3.33$, $p < 0.01$), RE scale ($t = -2.65$, $p < 0.01$), AC scale ($t = -2.81$, $p < 0.01$), MS scale ($t = -2.12$, $p < 0.05$), and TG scale ($t = -2.38$, $p < 0.05$) than the undergraduate students, as shown in Table 7. That is, the graduate students, when compared with undergraduate students, tended to prefer u-learning environments in which they could have more opportunities to keep continuous track of their learning, to attain authentic information based on the natural world, to browse documents and information based on their requirements, to get various relevant information sources, and to receive TG at the right time and in the right place. That is, the students in the advanced grade level (i.e. graduate level) tended to show stronger preferences for or demanded more from the features of the constructivist u-learning environments than did those in the lower grade level (i.e. undergraduate level).

Table 6. Gender comparisons of the students' scores for the CULES scales.

Scale	Gender (n)	Mean	SD	t
Ease of use	Male (116)	4.36	0.71	–0.76
	Female (99)	4.43	0.67	
Continuity	Male (116)	4.15	0.67	–0.15
	Female (99)	4.16	0.62	
Relevance	Male (116)	4.21	0.70	–1.90
	Female (99)	4.38	0.57	
Adaptive content	Male (116)	4.32	0.69	–0.58
	Female (99)	4.37	0.54	
Multiple sources	Male (116)	4.17	0.75	–1.28
	Female (99)	4.29	0.64	
Timely guidance	Male (116)	4.17	0.73	–0.77
	Female (n99)	4.24	0.59	
Student negotiation	Male (116)	4.13	0.81	–0.72
	Female (99)	4.21	0.68	
Inquiry learning	Male (116)	4.16	0.75	–1.65
	Female (99)	4.32	0.64	

CULES, constructivist context-aware ubiquitous learning environment survey.

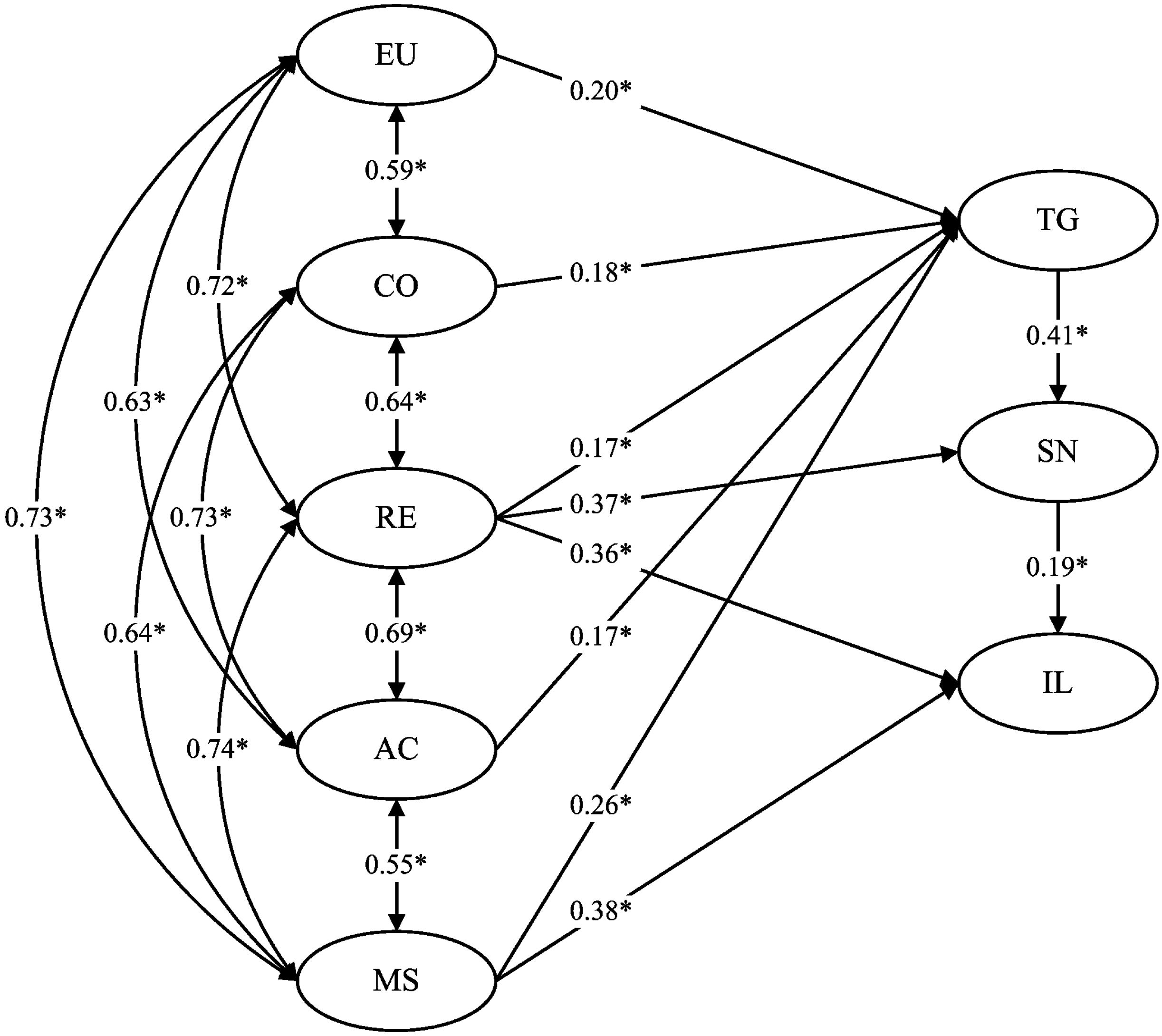

Fig 1 Structural model of the relationships between the technical–content and the cognitive aspects.
Notes: Significant *t*-value, $p < 0.05$. EU, ease of use; CO, continuity; RE, relevance; AC, adaptive content; MS, multiple sources; TG, timely guidance; SN, student negotiation; IL, inquiry learning.

Discussion and conclusion

This study was conducted to examine the reliability and validity of the CULES and to investigate the relationships between the technical–content and the cognitive aspect. Using exploratory factor analysis and SEM analyses with LISREL, the results showed the high reliability and validity of CULES for exploring students' preferences in constructivist u-learning environments. The fit measures for the structural model of CULES also showed a highly acceptable fit.

The major findings of this study reveal that the variety of authentic information from the real world plays an important role in u-learning environments. The positive predictions of the 'RE' on all scales of the cognitive aspect indicated that, when designing u-learning environments, educators should, in particular, provide authentic information and close-to-real-life situations, resulting in the students' preferences for engaging in cognitive activities. This finding is consistent with the fundamentals of u-learning that u-learning environments can help students to learn in authentic situations (Hwang *et al*. 2008; Yang *et al*. 2008; Peng *et al*. 2009). Moreover, u-learning environments can be created to provide the right observational data (e.g. text, voice data, and image data) for the right learners at the right

Table 7. Students' preferences in constructivist u-learning environments among groups of different grades.

Scale	Grade (n)	Mean	SD	t
Ease of use	Undergraduate (146)	4.35	0.72	–1.46
	Graduate (69)	4.49	0.62	
Continuity	Undergraduate (146)	4.06	0.65	–3.33**
	Graduate (69)	4.37	0.59	
Relevance	Undergraduate (146)	4.21	0.68	–2.65**
	Graduate (69)	4.46	0.55	
Adaptive content	Undergraduate (146)	4.26	0.65	–2.81**
	Graduate (69)	4.51	0.53	
Multiple sources	Undergraduate (146)	4.16	0.71	–2.12*
	Graduate (69)	4.37	0.67	
Timely guidance	Undergraduate (146)	4.13	0.66	–2.38*
	Graduate (69)	4.36	0.67	
Student negotiation	Undergraduate (146)	4.10	0.72	–1.85
	Graduate (69)	4.30	0.79	
Inquiry learning	Undergraduate (146)	4.18	0.69	–1.60
	Graduate (69)	4.34	0.73	

$*p < .05$; $**p < .01$.

time and in the right place (Hwang *et al*. 2008; Chu *et al*. 2010), many of which are difficult to achieve in the conventional classroom. Hence, it is obvious that diverse realistic information sources are essential elements in u-learning environments, which could enhance students' preferences for TG, SN, and IL activities.

By interviewing a group of college students about their experiences regarding u-learning, Tsai *et al*. (2011) have suggested that the issue of inquiry practices should be emphasized in u-learning environments. Considering the structural model of the relationships between the technical–content and the cognitive aspects, this study revealed that when increasing opportunities for developing students' inquiry-learning abilities, educators should provide the support of all the technical, content, and cognitive aspects. Hence, if u-learning environments can provide technical, content, and cognitive assistance, the students are more likely to be interested in the inquiry activities, such as solving problems or in-depth knowledge exploration. This implies that developing students' inquiry-learning abilities is difficult and quite complicated in u-learning environments. In addition, this finding is consistent with the results reported by Lin *et al*. (2009). According to their study, inquiry-based activities and meaningful interactions between peers and teachers may be beneficial in fostering students' perceptions of their learning environment.

Moreover, this study also investigated the roles of gender and grade level in the students' preferences in constructivist u-learning environments. The results revealed that males and females had similar preferences. Similar findings were reported by some studies that suggested that the preferred or well-established constructivist learning environments are equally appreciated by both males and females (Chuang & Tsai 2005; Chu & Tsai 2009). In addition, the analysis of grade-level differences in the CULES responses supported that the students in the advanced grade (i.e. the graduate students) tended to have stronger preferences for or demand more from the features of the constructivist learning environments, similar to the finding of Tsai (2008). This finding is likely to apply across Internet-based learning and u-learning. Hence, for these students, educators or designers should pay more attention to creating u-learning environments, which can provide more opportunities to satisfy their demands or preferences.

This study has undertaken to gain an initial understanding of students' preferences in constructivist u-learning environments. The current model of CULES, however, only involves the technical, content, and cognitive aspects. To investigate further students' perspectives of u-learning environments, future studies can explore more aspects or variables such as metacognitive activities. This study also encourages future studies to use reverse wording to develop an optimized CULES. In addition, Ford and Chen (2001) found that the matches of students' cognitive styles and instructional presentation styles influence students' learning performance.

Hence, future studies can explore the relationship between students' preferences in constructivist u-learning environments and learning outcomes in these environments. Such investigation could provide concurrent validity and predictive validity of the CULES instrument. In addition, future studies can also be conducted to examine how the measures on these CULES subscales are correlated with other students' personal factors such as prior knowledge, motivation, as well as some process-oriented measures such as students' engagement in learning processes. Again, these studies are crucial to ensure the concurrent validity and predictive validity of the CULES. Chuang *et al*. (2008), Fraser (1998), and Tsai (2008) have all suggested that educators should investigate the possible gap between students' actual perceptions toward certain learning environments and their preferences, and utilize such information to improve existing learning systems or to develop new learning environments. Hence, exploring the possible gap between students' actual perceptions and preferences in existing u-learning environments may be necessary.

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Appendix: The CULES questionnaire items

Ease of use scale (EU)

When navigating u-learning environments, I prefer that they

- have good wireless communication,
- have user-friendly context-aware devices,
- take only a short time to learn how to operate mobile devices, and
- have user-friendly mobile devices.

Continuity scale (CO)

When navigating u-learning environments, I prefer that they can

- record a learning portfolio to promote my learning,
- provide the functions of recording what I have learned,
- provide the tools to continue with my learning, and
- record the learning path that I have already been on.

Relevance scale (RE)

When navigating u-learning environments, I prefer that they

- present information that is relevant to me,
- contain meaningful information for learning,
- present realistic tasks, and
- show how complex real-life environments are.

Adaptive content scale (AC)

When navigating u-learning environments, I prefer that they can

- provide information which I need, e.g. documents, images, voice, etc.,
- provide a correct way to learn what I should know,
- provide information in which I am interested, and
- provide various sorts of information to choose from.

Multiple sources scale (MS)

When navigating u-learning environments, I prefer that they can

- discuss a learning topic through various perspectives,
- present a learning topic using different methods,
- offer various information sources to explore a learning topic, and
- connect to rich relevant web resources.

Timely guidance scale (TG)

When navigating u-learning environments, I prefer that they can

- provide useful feedback to guide learning at the right time and in the right place,
- provide meaningful questions to promote thinking at the right time and in the right place,
- provide experts' guidance to facilitate advanced learning, and
- offer timely guidance.

Student negotiation scale (SN)

When navigating u-learning environments, I prefer that

- I can discuss with other students how to conduct investigations,
- I can get the chance to talk to other students,
- other students can discuss their ideas with me, and
- I can ask other students to explain their ideas.

Inquiry learning scale (IL)

When navigating u-learning environments, I prefer that

- I can carry out investigations to test my own ideas,
- I can conduct follow-up investigations to answer my new questions,
- I can design my own ways of investigating problems, and
- I can find out answers to questions by investigation.

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