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Cognitive–metacognitive and content-technical aspects of constructivist Internet-based learning environments: a LISREL analysis

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Abstract

Through a LISREL analysis, this study validated the Constructivist Internet-based Learning Environment Survey (CILES). CILES consisted of six scales, sorted by two aspects. The first aspect, the cognitive–metacognitive aspect, included the scales of student negotiation, inquiry learning, and reflective thinking, whereas the second aspect, the content-technical aspect, involved the scales of Relevance, Ease of Use, and Challenge. A LISREL structural model was also proposed to examine the relationships between students' responses across these two aspects. Survey responses gathered from 483 high school students in Taiwan were the research data for this study. The results from the LISREL confirmatory analysis showed that CILES had highly satisfactory validity and reliability to assess students' preferences for constructivist Internet-based learning environments. Moreover, the structural model indicated that the Internet learning environments that challenged students' existing concepts could facilitate their preferences for student negotiation, inquiry learning and reflective thinking activities. It is proposed that the Internet can have rich connections with numerous resources and a variety of perspectives, thus constructing appropriate learning environments to provide different kinds of challenges for learners.

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1. Introduction

The theory of constructivism has been one of the major conceptual frameworks which guide and shape contemporary educational reforms and practices (Fosnot, 1996; Wilson, 1996). Although there may be many forms of constructivism, the constructivists generally assert that knowledge is actively constructed by individuals, and that social interactions with others also play an important role in the construction process (Perkins, 1999; Tsai, 1998, 2000). From this perspective, instruction should encourage students' autonomy, address or even challenge students' prior knowledge, and facilitate student-to-student as well as student-to-teacher interactions. Therefore, the constructivist learning environments should provide students with the opportunities to negotiate ideas, conduct inquiry and reflect their thoughts, thus enhancing their cognitive and metacognitive outcomes. In this way, learners are engaged in meaningful learning and higher-order thinking.

Recently, researchers in the field of educational technology have also applied the constructivist theory to Internet-based or Web-based instruction (e.g., Tsai, 2001a; Yakimovicz & Murphy, 1995). Internet-based or Web-based instruction provides learning environments which concur with aforementioned ideas about the practice of constructivist education. For instance, the hypertextual nature and rich connections of Internet-based instruction offer higher flexibility and more alternatives for instructional content, which may encourage students' autonomy and facilitate their inquiry and reflective thinking. In addition, e-mail or Internet-based communications may also facilitate more student-to-student and student-to-teacher interactions and negotiations (Chou & Tsai, 2002). Therefore, the features of Web-based instruction, from many perspectives, show congruence with the current practice of constructivism. Hence, Relan and Gillani (1997) have defined Web-based instruction as "the application of a repertoire of cognitively oriented instructional strategies implemented within a *constructivist* and collaborative learning environment, utilizing the attributes and resources of the World Wide Web" (p. 43, italics added).

Numerous studies have suggested that learners' perceptions of the learning environment will guide their attitudes, behaviors and ways of knowledge construction in that environment (Dart et al., 1999; Fraser, 1998). Some educators and researchers have proposed that there are some congruencies between the constructivist theory and the Internet-based instruction. In addition, a few successful cases integrating constructivist concepts and Internet-based learning have already been reported (Huges & Daykin, 2002; Hurley, Proctor, & Ford, 1999). However, in order to implement these ideas into instructional practices in the future or in more classrooms, a careful investigation of students' perceptions for constructivist Internet-based learning environment is valuable.

In this paper, students' perceptions toward constructivist learning environments involved two aspects, one was the content-technical aspect and the other was the cognitive and metacognitive aspect. The content-technical aspect explored students' preferences for the relevance and challenge (to prior knowledge) of Internet-based instructional materials, and the Ease of Use for the Internet learning systems. The cognitive and metacognitive aspect assessed learners' preferences for some cognitive and metacognitive activities in Internet-based learning environments, such as student negotiation, inquiry learning and reflective thinking. These mental activities, clearly, involve higher-order thinking, concurring with the rationale of applying constructivism to educational practice.

In addition, this paper asserted that students' perceptions toward the content-technical aspect might have been the basis for their preferences for processing some cognitive and metacognitive activities in the Internet-based learning environments. For instance, if the Internet systems are not user-friendly, students cannot engage in student negotiations. Or, if the instructional content provided by the Internet environments does not challenge students' existing ideas or relate to their prior knowledge, inquiry learning and reflective thinking will rarely occur. Therefore, the current study examined how students' perceptions for the content-technical aspect of Internet-based learning environments may have played a role in their preferences for cognitive and metacognitive activities in these environments. The Linear Structure RELationships (LISREL) analysis is a technique commonly used for the analysis of latent variables, and it can be used to confirm the validity of the scales of an instrument and assess the structural relationships among the scales (Jöreskog & Sörbom, 1989; Kelloway, 1998). The LISREL method was utilized as the major statistical analysis tool for this study. In sum, through the LISREL analysis, the main purposes of this study were:

1. To validate an instrument for assessing students' preferences toward constructivist Internet-based learning environments.
2. To examine the effect of students' preferences for the content-technical aspect of Internet learning environments on those for the cognitive and metacognitive aspect.

2. Methodology

2.1. Participants

A sample of senior high school students was selected from the north, central, and south region of Taiwan with the sample-size ratio of 3 to 2 to 2, which roughly represented the actual ratio of regional student population, to participate in this study. They came from seven senior high schools. The sample in this study was independent that used in Chuang and Tsai (submitted for publication), which included 727 junior and senior high school students in Taiwan. Case-wise deletion was applied for the small proportion of missing values. The final sample comprised 483 participants, whose age ranged from 14 to 18 years old (mean = 15.80, SD = 0.75); there were approximately 55.6% male and 44.4% female participants. Over 95% of these participants had at least one computer at home, and 88% of these students had access to the Internet while at home. They were across different academic backgrounds. That is, these participants were from a range of academic achievement and majors. The sample size of 483 was appropriate for the analysis of LISREL method when using the instrument such as that in this study.

2.2. Instrument

Chuang and Tsai (submitted for publication) used the Constructivist Multimedia Learning Environment Survey developed by Maor (2000) and modified into the Constructivist Internet-based Learning Environment Survey (CILES) to investigate students' perceptions toward constructivist-oriented, Internet-based learning environments. CILES is comprised of two aspects and a total of six scales, and there are five items in each of the scales, shown in Table 1. The first

Table 1
Aspects, scales and items of the CILES survey

Aspect I: Cognitive and metacognitive activities in the Internet-based learning environment In the Internet-based learning environment, I prefer that...		
Student negotiation	Sn1.	I can get the chance to talk to other students
	Sn2.	I can discuss with other students how to conduct investigations
	Sn3.	I can ask other students to explain their ideas
	Sn4.	Other students can ask me to explain my ideas
	Sn5.	Other students can discuss their ideas with me
Inquiry learning	Il1.	I can find out answers to questions by investigation
	Il2.	I can carry out investigations to test my own ideas
	Il3.	I can conduct follow-up investigations to answer my new questions
	Il4.	I can design my own ways of investigating problems
	Il5.	I can approach a problem from more than one perspective
Reflective thinking	Rt1.	I can think deeply about how I learn
	Rt2.	I can think deeply about my own ideas
	Rt3.	I can think deeply about new ideas
	Rt4.	I can think deeply how to become a better learner
	Rt5.	I can think deeply about my own understanding
Aspect II: The content and technical attributes in the Internet-based learning environment When navigating in the Internet-based learning environment, I prefer that it...		
Relevance	Re1.	Shows how complex real-life environments are
	Re2.	Presents data in meaningful ways
	Re3.	Presents information that is relevant to me
	Re4.	Presents realistic tasks
	Re5.	Has a wide range of information
Ease of use	Eu1.	Has an interesting screen design
	Eu2.	Is easy to navigate
	Eu3.	Is fun to use
	Eu4.	Is easy to use
	Eu5.	Takes only a short time to learn how to use
Challenge	Ch1.	Makes me think
	Ch2.	Is complex but clear
	Ch3.	Is challenging to use
	Ch4.	Helps me to generate new ideas
	Ch5.	Helps me to generate new questions

aspect (Aspect I) of the CILES explores students' preferences for the cognitive and metacognitive process of learning in Internet environments as mentioned above. This aspect includes three scales: student negotiation, inquiry learning, and reflective thinking because these three scales are related to students' cognitive and metacognitive growth in learning. The second aspect (Aspect II) investigates students' preferences for the content-technical part of the environments, including scales of Relevance, Ease of Use, and Challenge. These three scales examine the content and technical characteristics of an Internet learning environment. Participants responded to the questionnaire based on a five-point Likert scale, ranging from strongly disagree (scored as 1) to strongly agree (scored as 5).

2.3. Data analysis

Students' preferences toward the content-technical aspect of Internet-based learning environments (Aspect II) were viewed as predictors to explain their cognitive and metacognitive preferences when learning in those environments (Aspect I). That is, the structural or casual relationships between content-technical scales and cognitive–metacognitive scales, through a LISREL analysis, were explored. LISREL is a computer program for covariance structure analysis, and its prevalent use has always identified the name of the program with the statistical procedures it conducts. LISREL is perceived as the most general method for carrying out confirmatory factor analysis and the causal relationships among latent variables (Anderson & Gerbing, 1988; Jöreskog & Sörbom, 1989). LISREL version 8.2 was used throughout the analyses.

3. Results

3.1. CILES validation

Through a LISREL confirmatory factor analysis, the items for each scale of CILES were examined for convergent validity and construct validity. Convergent validity tests the relationship among items in the same construct (scale). All of the *t*-values of items showed statistical significance at the 0.05 level (Table 2), indicating that all of those five items within each scale were highly correlated with each other and, therefore, revealed convergent validity. In addition, construct validity was established by examining the extracted variance of each scale by the factor analysis. It was found that the items representing each individual scale accounted for between 52% and 73% of variance.

The reliability of CILES was demonstrated by examining the composite reliability coefficient. Shown in a column of Table 2, all of these coefficients were over 0.84 and the overall instrument reliability reached 0.97. Therefore, the instrument reliability was established. The reliability coefficients were very similar to those reported by Chuang and Tsai (submitted for publication) by an exploratory factor analysis of CILES based on the data collected from another group of Taiwanese high school students. In sum, the results from Table 2 demonstrate high validity and reliability of the CILES instrument.

Table 2
Instrument validation

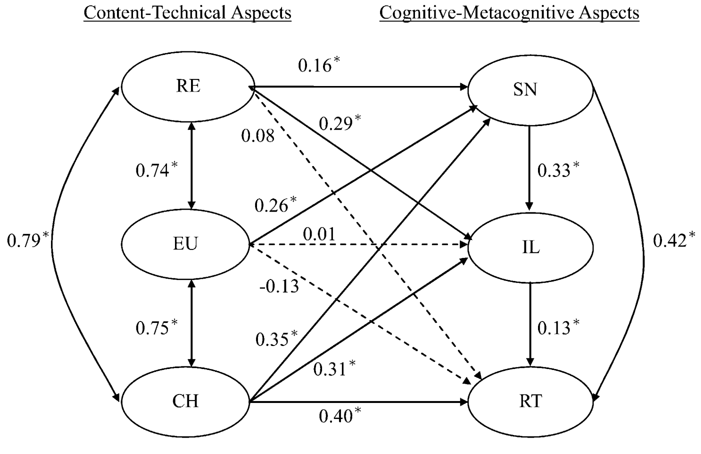
Scale	Item	Factor loading	*t*-value	Average variance extracted	Composite reliability[a]	Subscale score	
						Mean	SD
Student Negotiation	Sn1	0.64	18.68*	0.69	0.92	4.05	0.73
	Sn2	0.63	17.55*				
	Sn3	0.70	20.80*				
	Sn4	0.77	22.80*				
	Sn5	0.75	23.02*				
Inquiry Learning	Il1	0.69	19.55*	0.68	0.91	4.20	0.70
	Il2	0.68	19.51*				
	Il3	0.70	19.63*				
	Il4	0.64	16.76*				
	Il5	0.64	17.67*				
Reflective Thinking	Rt1	0.70	18.52*	0.52	0.93	4.20	0.73
	Rt2	0.71	19.55*				
	Rt3	0.72	19.73*				
	Rt4	0.74	19.18*				
	Rt5	0.65	18.39*				
Relevance	Re1	0.62	18.98*	0.69	0.91	4.33	0.67
	Re2	0.62	23.57*				
	Re3	0.66	23.19*				
	Re4	0.66	22.54*				
	Re5	0.63	21.83*				
Ease of Use	Eu1	0.59	18.13*	0.67	0.91	4.29	0.72
	Eu2	0.70	23.23*				
	Eu3	0.71	22.62*				
	Eu4	0.69	21.65*				
	Eu5	0.75	22.58*				
Challenge	Ch1	0.61	20.50*	0.73	0.84	4.11	0.64
	Ch2	0.44	10.82*				
	Ch3	0.53	13.87*				
	Ch4	0.66	22.42*				
	Ch5	0.64	20.58*				

* $p < 0.05$.

[a] Instrument reliability: 0.97.

3.2. Structural model

The proposed structural relationships between variables can be conducted through the LISREL analysis (Kelloway, 1998). The three scales related to student's perceptions of the content-technical learning environment (described in Aspect II) were used as predictor variables, and the other three scales related to students' cognitive and metacognitive experiences of the learning environment (Aspect I) were used as the outcome variables for the analysis. The structural model of this study is presented in Fig. 1.



*Significant t-value, $p < 0.05$.

Note: Chi-square = 1427.12 ($p < 0.01$);

Chi-Square per degree of freedom = 2.95;

RMSEA = 0.074;

NFI = 0.91;

NNFI = 0.91;

CFI = 0.92.

RE = Relevance; EU = Ease of Use; CH = Challenge; SN = Student Negotiation; IL = Inquiry Learning; RT = Reflective Thinking.

Fig. 1. Structural model and LISREL estimates.

The fit of the model was evaluated with various measures (Bentler, 1995; Sörbom & Jöreskog, 1982). Kelloway (1998) has suggested that the use of chi-square test is reasonable when the study involves a large sample. However, as the chi-square is very sensitive to sample size, the degree of freedom can be used as an adjusting standard by which to judge whether chi-square is large or small (Jöreskog & Sörbom, 1989). Therefore, in this study, the chi-square per degree of freedom can be used, and a ratio below five shows reasonable fit while a ratio between one and two is excellent fit. The ratio of the model in Fig. 1 was 2.95, indicating a fairly good fit.

Other types of goodness-of-fit measures include Root Mean Squared Error of Approximation (RMSEA), normed fit index (NFI), non-normed fit index (NNFI), and the comparative fit index (CFI). A RMSEA value close to zero shows a near perfect fit. The NFI, NNFI, CFI are always between zero and one, with any value above 0.9 indicating a good fit and the value one suggesting a perfect fit. The model in Fig. 1 had a RMSEA of 0.074, and the NFI, NNFI, and CFI values over 0.9, showing that the model had a highly satisfactory fit.

Fig. 1 shows the summary of the maximum likelihood parameter estimates, lambda, and the significance of the t-values as indicated by asterisks for the model. The statistically significant relationships are shown in solid lines. Relevance, Ease of Use, and Challenge were all significant predictors to student negotiation. Relevance and Challenge were the predictors to inquiry learning. Challenge was the only significant predictor to reflective thinking.

4. Discussion

As presented previously, one major purpose of this study was to develop a structural model to represent the causal relationships between the two aspects of CILES. The three scales of Aspect II (content-technical) were the predictor variables, and those of Aspect I (cognitive–metacognitive) were the outcome variables. Goodness-of-fit measures of the model, including chi-square per degree of freedom and other indices, revealed that this model had a highly acceptable fit. Some further discussion for the relationships among the scales is presented below.

4.1. Student negotiation scale

According to Fig. 1, all three predictor variables, Relevance, Ease of Use, and Challenge, were statistically significant predictors to student negotiation. Items in student negotiation described students' preferences for the communications in learning environments. From a Relevance point of view, if a student prefers realistic, close to real-life learning experiences, he/she is more likely to be enthusiastic about the learning process and to discuss his/her ideas with peers. Similarly, if the Internet learning environment is user-friendly, the students will have more free time for extra communication and discussion rather than trying to make sense of the interface. The Ease-of-Use feature of an Internet environment, clearly, would also facilitate learner communication. Furthermore, a challenging instruction would encourage students to express and exchange their ideas. For instance, if the instructional content involves some challenging tasks, students may need to discuss with each other to find ways to resolve them. Based upon these findings, it is reasonable to expect the effects of Relevance, Ease of Use, and Challenge on student negotiation.

4.2. Inquiry learning scale

Students' preference for inquiry learning, as an outcome variable, was predicted by Relevance and Challenge preferences. The preferences of learning environments with real-life and challenging features would obviously affect students' views toward inquiry-based learning, because inquiry learning is often based upon authentic tasks and skills for solving open-ended and challenging problems, which are related to Relevance and Challenge scales. To use science as an example, the *National Science Education Standards* (National Research Council, 1996) defines inquiry as follows:

> Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (p. 23).

Although this viewpoint is generated from the field of science education, it could be applied to inquiry learning in general. This definition helps to explain the result of this part that inquiry activities start from a problem based on the natural world (Relevance). In addition, inquiry activities that aim to study the natural world include asking questions and idea interaction; therefore, inquiry learning would definitely be resulted from the challenging to prior knowledge and questioning of ideas (Challenge).

The model showed that the Ease of Use scale was not a predictor to Inquiry Learning. It is possible that, whether an Internet environment is easy to use or not, students' preferences for Ease of Use only represent a technical aspect of the environment, which is not related to the higher-level, cognitive preferences toward inquiry. The user-friendly feature of a learning environment may save a learner's time to conduct more investigation, but, reasonably, Ease of Use would not strictly limit a learner's use of inquiry-based investigations.

4.3. Reflective thinking scale

In light of the structural model in Fig. 1, the last scale in Aspect I, reflective thinking, could be predicted only by the Challenge scale, but not by Relevance or Ease of Use. Reflective thinking involves metacognitive activities of the instruction, while environments presenting challenging information or problems can promote students' higher-order thinking skills and target on the zone of proximal development (Vygotsky, 1978). Vygotsky suggests that a learner's potential development level can be scaffolded based upon his/her actual development level and the teacher's assistance, and the scaffolding process requires the inputs derived from relatively challenging learning environments. Pithers and Soden (2000) have reviewed educational research studies related to critical thinking and have concluded that scaffolding could facilitate higher-order thinking and metacognitive abilities. The results from our study concur with these reviewed research articles, suggesting that challenging environments would generate reflective and metacognitive thinking.

According to the structural model, Relevance and Ease of Use scales did not play any role in the reflective thinking scale, and possible explanations are given below.

1. Relevance features are related to how students interpret learning materials in a more concrete way, pertaining to the cognitive level of thinking, but not yet to the metacognitive level.
2. Similar to the reason given for Inquiry Learning scale, Ease of Use deals with the technical aspect of the Internet as a learning TOOL; therefore, Ease of Use does not directly affect the higher-order thinking activities such as reflective thinking, which could be interpreted from the structural model.

5. Summary

The results from this study suggested that Student Negotiation scale was affected most extensively by all of the three content-technical scales, the Inquiry Learning scale was influenced by both the Relevance scale and Challenge scale, and the reflective thinking scale was affected only by the Challenge scale. Therefore, these findings likely implied that the Ease of Use scale had the least influence on student preferences for cognitive/metacognitive activities, the Relevance scale had a moderate effect, and the Challenge scale had the most comprehensive influence on these mental activities.

6. Implications and future research

Constructivist learning environments aim to promote higher-order thinking skills and open-ended inquiry. Resnick (1987) once defined higher-order thinking as developing the combinational abilities of problem solving, metacognition, understanding, and motivation. Kirkwood (2000) extended Resnick's idea and argued "problem solving can be viewed as a goal-oriented process which requires the integrated use of a range of higher-order thinking skills (p. 511)." Resnick's and Kirkwood's arguments are fairly close to the current movement toward constructivist teaching and learning, which is, at least, partly presented in the CILES instrument.

Based on the findings of this study, educators who use or will use Internet learning environments need to be cautious about the relationship between the intended outcomes of student learning and the design of learning environments. If student negotiation and communication are to be addressed, then content relevance to the actual world, the ease-of-use characteristics of the Internet environments, and the challenging nature of the instruction should all be carefully acknowledged. For Internet-based instruction intending to develop inquiry-learning abilities, learning materials that show relevancy and appropriate challenges to prior knowledge need to be emphasized. To develop students' metacognitive skills such as reflective thinking abilities, educators should focus more on the challenging feature provided by learning environments. This does not mean that relevance and ease-of-use features are not important for developing reflective thinking, but the environments with challenging learning content are likely to be more vital for building the foundations of higher-order thinking abilities.

In light of the structural model, the creation of challenging learning environments that carefully address students' existing concepts may be an essential prerequisite for implementing Internet-based constructivist-oriented instruction to promote student negotiation, inquiry learning and reflective thinking. This finding is consistent with the perspective proposed by educators and psychologists that meaningful learning occurs when students' prior knowledge is related and properly challenged (Ausubel, Novak, & Hanesian, 1978; Driver & Oldham, 1986; Tsai, 2001a). In challenging environments, cognitive disequilibrium is engendered, and thus knowledge structures are refined and extended. In addition, the Internet has rich connections with numerous resources and a variety of perspectives, thus constructing appropriate learning environments to provide different kinds of challenges for learners (Tsai, 2001b, 2004). Educators are encouraged to make use of the merits of the Internet technology to create learning environments with the challenging feature for students.

This study investigated senior high school students' general preferences for constructivist-oriented Internet-based learning environments. Future research could examine the same preferences in specific knowledge domains, such as science, language, and history, to reveal possible preference differences related to various knowledge domains. The revealed differences can help experts in instructional technology to design better Internet learning environments for a particular domain of knowledge. In order to acquire a better picture of students' views about Internet-based learning environments, other variables, such as students' motivational orientations and epistemological beliefs (Hofer & Pintrich, 1997; Linnenbrink & Pintrich, 2002; Tsai, in press), which are related to cognitive and metacognitive activities, can also be explored in the future for their connections with students' CILES responses. After the instrument validation in this study, the next step for the researchers is to use this instrument to assess existing Internet-based learning environments. Therefore, developing a similar CILES form to assess students' *actual* perceptions, not only preferences, toward certain existing Internet learning environments may be highly necessary.

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