Original article

Learning effectiveness in a Web-based virtual learning environment: a learner control perspective

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Abstract Web-based technology has a dramatic impact on learning and teaching. A framework that delineates the relationships between learner control and learning effectiveness is absent. This study aims to fill this void. Our work focuses on the effectiveness of a technology-mediated virtual learning environment (TVLE) in the context of basic information technology skills training. Grounded in the technology-mediated learning literature, this study presents a framework that addresses the relationship between the learner control and learning effectiveness, which contains four categories: learning achievement, self-efficacy, satisfaction, and learning climate. In order to compare the learning effectiveness under traditional classroom and TVLE, we conducted a field experiment. Data were collected from a junior high school of Taiwan. A total of 210 usable responses were analysed. We identified four results from this study. (1) Students in the TVLE environment achieve better learning performance than their counterparts in the traditional environment; (2) Students in the TVLE environment report higher levels of computer self-efficacy than their counterparts in the traditional environment; (3) Students in the TVLE environment report higher levels of satisfaction than students in the traditional environment; and (4) Students in the TVLE environment report higher levels of learning climate than their counterparts in the traditional environment. The implications of this study are discussed, and further research directions are proposed.

Key words: effectiveness, learner control, technology-mediated virtual learning environment (TVLE)

Introduction

Because of the easily accessibility of Web-based technology, there has been a noticeable transformations in the learning and teaching processes (Beller & Or 1998; Kiser 1999). Technology-mediated virtual learning environment (TVLE) are defined as 'computer-based environments that are relatively open systems, allowing interactions and knowledge sharing with other participants and instructors' and providing access to a wide range of resources (Wilson 1996). The value of a TVLE is to fully bring out the characteristics of both 'Learning Any Where' and 'Learning Any Time', i.e., learning in an asynchronous way. The purpose of a TVLE is to emphasize on self-control, diffuse thinking models, diverse viewpoints, and independent thinking (Hill & Hannafin 1997).

Proponents of TVLEs argued that they can potentially eliminate the barriers while providing increased convenience, flexibility, currency of material, student retention, individualized learning, and feedback over

Accepted: 10 November 2004
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traditional classrooms (Massy & Zemsky 1995; Hackbarth 1996; Kiser 1999). Although much of the literature emphasized the potential value of Web technology in educations, others specified its drawback (Hara & Kling 2000). Students in TVLEs may have feelings of isolation (Brown 1996), frustration, anxiety, and confusion (Hara & Kling 2000). According to Maki *et al*'s (2000) research, learner's learning effectiveness, and interest in the subject matter may also be reduced.

Students are the primary participants in any learning environment. The main characteristic that differentiates between TVLEs and the traditional learning environment is the use of technology and shift of control and responsibility to the learners. Although previous research has discussed and compared the learning effectiveness between TVLE and traditional environment, there are relatively few studies examining the causality of learning effectiveness from the learner control perspective. Thus, this study delineates the relationships between learner control and learning effectiveness. Drawing on technology-mediated learning theory (Alavi *et al*. 1995; Leidner & Jarvenpaa 1995; Piccoli *et al*. 2001), we developed a conceptual framework that identifies the primary dimensions of a TVLE and their relationships with learning effectiveness. We then conducted an experiment design that reports the results of a preliminary test of a subset of the relationships identified by the framework. We limit our inquiry to basic information technology (IT) skills, although our conceptual framework has broader utility. We compared a TVLE to a traditional classroom-based course designed to introduce students to the fundamental concepts of computing principles and user skills. Since basic IT skills become obsolete very fast and owing to the growing needs for academic and business environments, we choose to focus on basic IT skills.

Theory and hypotheses development

Learner control

Learner control refers to 'instructional designs where learners make their own decisions concerning the aspects of the path, flow, or events of instruction'. (Williams 1996) In other words, the learner can decide to a certain extent that students exert control over the pace, sequence, and content of instruction in a learning environment (Milheim & Martin 1991). Content represents the instructional material presented to the learner. Learning pace refers to the rate of presentation of the content and the time spent on individual component of content. Sequence stands for the representation order of the content that is accessed by learners (Milheim & Martin 1991).

The underpinnings of learner control contain three different types of theory – motivation theory (Keller 1983), attribution theory (Martin & Briggs 1986), and information processing theory (Gagne 1997). Proponents of learner control argued that students achieve better performance because of higher degrees of learner control. Performance is measured as lower errors on tests and higher learning satisfaction (Merrill 1994). Williams (1996) suggests that learner control may lead to positive results, because learner control is a way of allowing individual influences to exert a positive influence without trainer control.

Although the positive effect of learner control seems to appeal to most students, empirical findings remain inconclusive. Some studies show either the superiority or inferiority of learner control to traditional program control, but with the majority of the research indicating no significant difference between them (Reeves 1993; Williams 1996). Since individuals differ in their ability to make appropriate learning and instructing decisions, some learners may view less material and skip important instructional components because of the overestimation of their ability (Lepper 1985; Lee & Wong 1989; Reeves 1993).

Component display theory (CDT)

According to Clark's (1994) research, learning effectiveness is influenced by the instructional method embedded in the media presentation rather than the media itself. CDT (Merrill 1983) is a theory of instructional design that offers the guidelines of designing presentation forms as the basic components of a lesson. We adopted CDT as the design criteria for both the TVLE and traditional learning environment. Merrill (1983, 1994) specifies four major presentation forms: (1) *rule*: the fundamental rationale for a specific instructional method or a model of learning. For example, the objectivist or traditional model views learning as the transfer of knowledge to the learner;

(2) *example*: illustrations and explanations that specify the characteristics of a rule; (3) *recall*: remind students of the generality of the learning model; and (4) *practice*: to combine theory with practice by taking instances. In order to provide a student with a full range of learning and instructional tools, the presentation of each instructional component should contain all of the above forms. As a result, learners may decide the learning pace, the sequence of presentation, and the control over content. According to Merrill's theory (1983, 1994), when a course and its presentation form are designed based on CDT, it is assumed that students may have higher learning achievement provided that they have higher levels of learner control.

Learning effectiveness

In order to understand the impact of learner control on students' achievement, four antecedents of learning effectiveness in the TVLE are used. First, according to Merrill's research (1983, 1994), the number of errors on an achievement test following instruction represents one type of learning effectiveness. Since learners vary in their ability to gauge their progress and take advantage of a high level of control (Milheim & Martin 1991), learner control should be accompanied by aids for self-monitoring of progress (Williams 1996). In TVLE's environment, self-monitoring of progress can be easily fulfilled through practice assignments and discussions. Thus, we have the first hypothesis:

H1: Students in the TVLE achieve higher test scores than their counterparts in the traditional learning environment.

The second indicator of learning effectiveness is computer self-efficacy. Based on Bandura's (1986) definition, self-efficacy refers to people's judgements of their capabilities to attain designated types of performance. The main concern of self-efficacy is the judgements of what one can do with whatever one possesses. In the context of IT basic skills training, it is very important to evaluate the learners' propensity to actually apply what they have learned. In addition, students' confidence of their capabilities to use IT appropriately is also an indicator of computer self-efficacy. Compeau and Higgins (1995) defined computer self-efficacy as learner's judgement of his/her ability to complete a task using computers.

According to Keller's (1983) model of motivational instructional design, learner control usually enhances students' self-efficacy. Drawing on attribution theory, Martin and Briggs (1986) suggest that students who have more control over their instructional material, pace, and sequence usually ascribed the learning achievement to their own ability. As a result, learners who have more control of learning tend to feel that they can develop higher self-efficacy.

H2: Students in the TVLE will report higher levels of computer self-efficacy than their counterparts in the traditional learning environment.

Third, satisfaction has been a widely used indicator to evaluate learning effectiveness both in academic and industry (Alavi *et al*. 1995). The success of TVLEs may depend heavily on learners' acceptance of this new type of learning and instructing methods. Since previous experience is an important determinant of future attitudes (Eagly & Chaiken 1993), it is essential to evaluate students' learning satisfaction with the innovative way to learn in TVLEs. According to component display theory (CDT)(Merrill 1983) and the general control theory (Piccoli *et al*. 2001), higher degrees of learner control may increase student satisfaction (Merrill 1983; Williams 1996). With the help of TVLEs, students may participate in learning activities more flexibly than in the traditional learning environment. Learners decide when and where they prefer to learn at their own pace, and to focus on the content that they deem important. As a result, students' satisfaction tends to increase.

However, Williams (1996) argued that learners may feel frustrated because of the feelings of being unable to receive effective and timely advices from instructors in TVLEs environment. According to Maki *et al*'s (2000) research, the students in the traditional learning environment have higher levels of satisfaction with learning experience than in TVLEs. When individuals are confronted with a learning environment that uses a new technology and high level of learner control, they tend to have negative attitudes. Although these negative attitudes from learners lessen gradually, they do not entirely disappear (Wetzel *et al*.

1994). Although the perspectives concerning the satisfaction in TVLEs and traditional classroom differ radically, from the learner control viewpoint (Merrill 1983; Williams 1996), it seems reasonable to assume that the satisfaction for students in TVLE is higher than that in the traditional environment. Thus, we have the third hypothesis:

H3: Students in the TVLE will report higher levels of satisfaction than their counterparts in the traditional learning environment.

Finally, the emotional learning climate is also an important indicator of learning effectiveness. Some learning theories view learning as a social process that occurs more effectively through cooperative interpersonal interactions (Alavi *et al*. 1995). According to Vygotsky's (1978) research, learning is composed of social and knowledge exchanging activities that are initially shared among people but finally internalized and personalized by the individual. Piaget (1967) contends that the main purpose of social interactions is to shift an individual's thinking away from an egocentric perspective. While the learner possesses multiple perspectives that can challenge his/her initial understanding of a specific problem, the learner's motivation for learning is usually enhanced (Glaser & Bassok 1989). In TVLEs, the learning process contains a several of interactions and knowledge exchange among learners and between learners and instructors.

Group interactions for learning and knowledge sharing consist of socio-emotionally focused processes (Dennis & Valacich 1994). More specifically, based on McGrath's (1991) TIP theory – Time, Interactions, and Performance–group interactions contain three critical and concurrent functions – production, member support, and group well-being. Production function stands for the task formally assigned to a group. The purpose of group interactions is to solve a problem or learn a skill or concept, i.e., to complete the production function. Member support contributes to the satisfaction of individual members. Group well-being contributes to the group's emotional climate and viability as an intact social structure (Alavi *et al*. 1995). In the light of TIP theory, both socio-emotional and task-oriented behaviour is operated simultaneously in TVLEs learning environment. Thus, from the group interactions perspective, the measurement of learning effectiveness consists of three important factors – learning achievement (the production function), satisfaction (member support), and the perception of the emotional climate of the group or learning environment (group well-being).

According to media richness theory, an environment that conveys information and matches up to the learners' expectations will usually improve the group task performance and emotional climate. In TVLEs, learners can control the learning pace, sequence, and content. In comparison with the group interactions in the traditional environment, it seems easier for learners to reduce the uncertainty and equivocation in the TVLE, because they may ask experts or classmates to help them through communication media. Thus, we have the final hypothesis:

H4: Students in the TVLE will report more positive learning climate than their counterparts in the traditional learning environment.

Research design

Figure 1 identifies the basic components of our research framework. The basic research question is: what is the impact of learner control on learning effectiveness? Data were collected from a junior high school of Taiwan – Hsing-Kuo Junior High School (HKJHS). We used a 14-week field experiment adopting a two-group repeated design – TVLEs and traditional learning environment. A total of 210 students who were their first year in HKJHS participated in the experiment. One hundred and seven of the 210 students joined the treatment group; the others ($N = 103$) belonged to the control group. Subjects did not have prior knowledge of the selected course. Subjects were representatives of the traditional junior high school population. They were young (age ≤ 13, 88%), and fairly evenly distributed by gender (58.2% males, 41.8% female).

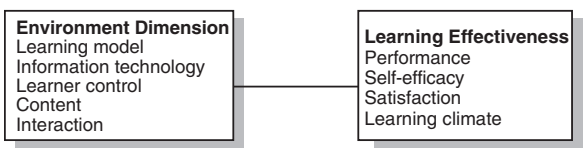

Fig. 1 Research framework.

The course is an introductory course of computer. The main content of the course includes: (1) basic architecture of computer and network, (2) introduction for Internet and Web, (3) introduction of the tools for word processing and presentation, for example, Microsoft Word, and Powerpoint; and (4) how to use e-mail, and Web browser. Both versions of the course, traditional and TVLE, were designed following the principles of CDT and included all four primary presentation forms – rule, example, recall, and practice. A set of identical teaching procedures and contents was devised to ensure the consistency between instructors and between treatments. In order to assure the consistency of learning models between instructors and between treatments, the primary researcher developed a set of procedures and monitored them. The primary researcher also monitored the interactions both in the TVLE and in the traditional classroom and provided direction and suggestions when necessary.

Assignments, exams, and deadlines were standardized and synchronized for TVLE and classroom. The contents of the homework and exam include the material covered by the course. For example, the students are asked to hand in a homework that contains a report using Word. The questions in the exams may include: (1) What are the meanings of BBS, freeware, CPU, megabyte (MB), flash memory, BYTE, and browser? (2) What is the correct format of an e-mail address?, and (3) What are the possible input/output devices of a computer? This study uses the scores from two tests – mid-term and final – to measure the learning performance. In order to keep the performance measurement of mid-term and final as independent as possible, the test material of the final exam only covers the course content taught after the mid-term.

In a preliminary survey, we measured demographics. Three traits of learners were examined: attitudes towards computer use, previous experience with computers, and anticipation of the course. We also conducted a quiz to test the learners' basic knowledge of the course material. A series of *t*-tests indicated no significant difference between the treatment and control group on these dimensions. Thus, we assume the homogeneity of pretreatment skills, attitudes, experience, and expectation.

Four sections of the target course were offered. Two of the sections belonged to the treatment groups, and the others were assigned to the control group. Two instructors participated in the experiment, and each of them taught one section in the traditional classroom and one section in the TVLE. In the traditional classroom, the teachers instructed and demonstrated specific software features. Instructors used an overhead projector and assigned standard homework to students every week. Students spent one-half of the class time in a computer laboratory where each student accessed a computer and completed the practice homework along with the instructor.

The TVLE was developed using the 'Ed Pilot interactive online system', which contains three layers to facilitate the creation and administration of online courses – the courses browser for both students and teachers, courses development tools for teachers, and the courses server for the system manager to administer the system. The TVLE is an open system to allow learners and instructors to interact through an electronic forum. Learners and instructors who participated in the class electronic discussion can make comments, raise questions, and responses in a synchronous or asynchronous fashion. The forum is publicly available to all users in TVLE, and the discussion can be threaded. Therefore, learners can easily access and read the information on different subjects. In addition, because of the threading of public communication, students can selectively retrieve the information and components that are interesting to them while skipping the others. As a result, students can control the learning content, pace, and sequence.

Because participants' interaction represents one of the characteristics of a TVLE, we conducted a post hoc analysis of the electronic logs to ensure that our course represents an appropriate operationalization of a TVLE. The messages fall into three categories: administrative, content related, and social. The first category refers to general announcements and questions (e.g. due dates, format of a report, scope, and the main theme of an exam). The second category refers to questions, answers, or comments regarding the learning material. The final category refers to social messages (e.g. interesting MP3 or singer). A total of 579 messages were recorded in the section we analysed. The results report an appropriate level of interaction. Most students participated in the online learning and discussion activities, with some being more active than others but with no students controlling the interaction.

Table 1. Multivariate test of significance

Effect	Wilks' Lambda	*F*	df	*P*	Estimated effect size	Observed power
Instructor	0.92	3.421	2;207	0.274	0.72	0.781
Learning environment	0.824	8.971	2;207	0.0001	0.169	0.998

During the first week of class, instructors taught the students in the treatment group how to use the online modules and available communication tools. During the second week of training, the students convened for 3 h in a computer lab on campus. In this training meeting, both instructors were available to provide guidance and answer questions concerning the introductory material of using TVLE. Since the amount of time that a teacher spent in instructing learners may have an impact on the learning effectiveness, the instructor time in TVLE and traditional classroom should be as close as possible. The instructor time of TVLE includes two parts: training the students to use online modules and tools, and synchronous and asynchronous interactions. On the other hand, the time spent in the traditional classroom contains three parts: instruction and demonstration ofsoftware features in a classroom, helping students to complete the practice assignment in a computer laboratory, and providing office hours to solve students' problems. In order to maintain equal instructor time, one of the researchers investigated and monitored the time spent in the variety of teaching activities. The researcher reported that there is significant difference in instructor time between TVLE and the traditional classroom.

In order to realize the effectiveness of the two teachers who participated in the experiment in delivering the underlying instructional method, we included instructor as a control variable. We conducted multivariate tests of significance that are shown in Table 1. Our results indicate that the two instructors were equally adept in delivering the teaching procedures. In addition, the results in Table 1 suggest a statistically significant effect of learning environment. The major difference between the two learning environments is the higher level of learner control provided by TVLE. In the TVLE, the learning is more flexible. Students can access the instructional material at any time and from any place equipped with the necessary software and hardware.

Data analysis and results

Validity and reliability

In order to operationalize the constructs of our research model, we used factor analysis. Factor analysis using principal components factor analysis with factor extraction and VARIMAX rotation was conducted to examine the unidimensionality/convergent and discriminant validity. The four commonly used decision rules were applied to identify the factors (Hair *et al*. 1995): (1) minimum eigenvalue of 1; (2) minimum factor loading of 0.4 for each indicator item; (3) simplicity of factor structure; and (4) exclusion of single item factors. Reliability was evaluated by assessing the internal consistency of the indicator items of each construct by using Cronbach's α, which is shown in Table 2. The results of factor analysis relating to unidimensionality/convergent validity are shown in Tables 3 and 4. A joint domain factor analysis was performed, including all of the items used to develop the research constructs. The result provides significant support for factorial/discriminant validity of the measurement scales.

Results of hypotheses tests

Grades on mid-term and final exams were adopted to measure student's achievement. Computer self-efficacy, satisfaction, and learning climate were measured

Table 2. Results of the reliability analysis

Construct	Variable	Cronbach's α
Learning effectiveness	Computer self-efficacy	0.8276
	Learning satisfaction	0.8625
	Learning climate	0.8558
Learner's self-report	Computer self-efficacy	0.7525
	Learning satisfaction	0.7638
	Learning climate	0.8719

Table 3. Factor analysis of learning effectiveness

Factor	Eigenvalue	Variance	Cumulative variance	Mean (SD)	Factor loading
Computer self-efficacy	1.221	13.563	60.298	3.979 (0.796)	
1. I was confident to learn online on my own time					0.831
2. I was confident to learn online at my own pace					0.842
3. I was confident to get a good grade in the course					0.704
4. I improved learning by repeatedly reviewing the course materials					0.735
5. I connected to the online course from the place I chose					0.513
6. I chose the appropriate learning environment to improve learning achievement					0.710
7. I made the most of internet to grasp the learning materials					0.753
8. I felt anxious because of computer incompetence					0.927
9. I employed the online information to learn and to motivate learning					0.690
Learning satisfaction	1.134	14.178	66.212	3.765 (0.869)	
1. I was satisfied with this learning experience					0.761
2. A wide variety of learning materials were provided in the course					0.763
3. I don't think that the course would benefit my learning achievement					0.971
4. I was satisfied with the immediate information acquisition					0.813
5. I was satisfied with the learning flexibility and independence of this course					0.820
6. I was satisfied with the instruction model					0.780
7. I was satisfied with the learning environment					0.753
8. I was satisfied with the overall learning effectiveness					0.693
Learning climate	2.208	22.082	57.144	3.773 (0.959)	
1. The course was interesting					0.734
2. It was important to choose the place to learn					0.744
3. I felt free to ask questions					0.560
4. I had more interaction and communication with classmates					0.606
5. I had more interaction and communication with the instructor					0.678
6. I think this learning environment was more interesting					0.644
7. I felt less pressure about this learning model					0.648
8. This learning model was boring					0.655
9. The learning climate was relaxing					0.758
10. The learning climate was enjoyable					0.824

through validated scales (Alavi *et al*. 1995; Compeau & Higgins 1995, Green and Taber 1980). Respondents were asked to indicate on five-point scales ranging from (1) strongly disagree to (5) strongly agree. The results of factor analysis and reliability relating to learner traits, learning effectiveness, and learner's self-report are shown in Tables 3 and 4. As indicated by these tables, all items loaded in the expected construct. As can be seen from Table 2, the reliability of the measures is at a satisfactory level.

Tests of the assumption of homoscedasticity and normality were based on repeated measure designs (Hair *et al*. 1995). Mean and standard deviations of learning achievement, self-efficacy, satisfaction, and climate are reported for both TVLE and traditional environments in Tables 5 and 6. We used 'independent samples *t*-test' to compare the different types of learning effectiveness between TVLE and traditional learning environments. As shown in Table 5, the grade of total – mid-term and final exam – in TVLE (84.67) is higher than that in the traditional environment (81.48). Thus, hypothesis 1 is substantiated. In order to examine whether the pattern of learner's achievement differed between the first and second data collection (i.e. mid-term and final), we adopted 'Pair-samples *t*-test'. From Table 7, the results show that no performance difference exists between the two data collections in the TVLE. However, students have lower

Table 4. Factor analysis of learner's self-report

Factor	Eigenvalue	Variance	Cumulative variance	Mean (SD)	Factor loading
Computer self-efficacy	1.261	14.010	64.971	3.716 (0.933)	
1. I was confident to learn online on my own time					0.755
2. I was confident to learn online at my own pace					0.859
3. I was confident to get a good grade in the course					0.711
4. I improved learning by repeatedly reviewing the course materials					0.721
5. I connected to the online course from the place I chose					0.612
6. I chose the appropriate learning environment to improve learning achievement					0.631
7. I made the most of internet to grasp the learning materials					0.845
8. I felt anxious because of computer incompetence					0.745
9. I employed the online resources to learn and to motivate learning					0.651
Learning satisfaction	2.122	26.531	60.844	3.858 (1.018)	
1. The learning experience with the TVLE was better than that with the traditional classroom					0.824
2. A wide variety of learning materials were provided in the TVLE					0.856
3. I don't think that Web-based learning would benefit my learning achievement					0.393
4. I was satisfied with the immediate information acquisition in the TVLE					0.739
5. I was satisfied with the learning flexibility and independence of the TVLE					0.648
6. I was satisfied with the Web-based instruction model					0.807
7. I was satisfied with the TVLE					0.736
8. I was satisfied with the overall learning effectiveness in the TVLE					0.796
Learning climate	1.926	19.256	69.476	4.015 (1.042)	
1. The course was more interesting in the TVLE					0.659
2. I was free to choose the place to learn in the TVLE					0.524
3. I felt free to post questions to the online discussion board in the TVLE					0.856
4. I had more interaction and communication with classmates in the TVLE					0.761
5. I had more interaction and communication with the instructor in the TVLE					0.749
6. I think the TVLE was more interesting					0.602
7. I felt less pressure about the Web-based learning model					0.802
8. The learning climate in the TVLE was relaxing					0.803
9. The learning climate in the TVLE was enjoyable					0.769
10. The learning climate in the TVLE was boring					0.747

TVLE, technology-mediated virtual learning environment.

Table 5. Means and standard deviations of learning performance.

	TVLE		
Variable (performance)	Midterm	Final	Total
n	107	107	
Mean	84.15	85.18	84.67
SD	10.42	8.32	
	Traditional Classroom		
Variable (performance)	Midterm	Final	Total
n	103	103	
Mean	84.52	78.44	81.48
SD	10.98	11.08	

TVLE, technology-mediated virtual learning environment.

final grades than their mid-term grades in the traditional environment, and the difference is statistically significant (Table 5).

The results of Table 6 suggesting the learning effectiveness – self-efficacy ($P = 0.011^{**}$), satisfaction ($P = 0.0001^{**}$), and climate ($P = 0.0001^{**}$) (Note: $^{**}P < 0.05$; $^{*}P < 0.1$) – in TVLE is significantly better than in the traditional learning environment. Therefore, hypotheses 2, 3, and 4 are all substantiated. The summary of our hypotheses test is shown in Table 8.

Limitations

There are three limitations in this study. First, we did not analyse the relationship between the time spent in

Table 6. Independent samples *t*-test: dependent variables

	N	Mean	SD	*F*	*t*-value	df	*P*
Computer self-efficacy							
TVLE	107	35.87	5.06	2.021	2.577	208	0.011**
Traditional classroom	103	34.13	4.67				
Learning satisfaction							
TVLE	107	31.10	4.55	0.722	4.424	208	0.0001**
Traditional classroom	103	28.19	4.97				
Learning climate							
TVLE	107	38.82	5.68	0.182	3.556	208	0.0001**
Traditional classroom	103	35.93	6.10				

**$P<0.05$; *$P<0.1$. TVLE, technology-mediated virtual learning environment.

Table 7. Paired samples *t*-test for performance of mid-term and final

Learning environment	*N*	SD	Correlation coefficient	df	*t*-value	*P*
TVLE	107	11.32	0.286	106	−0.939	0.350
Traditional	103	10.30	0.564	102	5.998	0.0001**

**$P< 0.05$; *$P<0.1$. TVLE, technology-mediated virtual learning environment.

Table 8. Results of hypotheses test

Hypotheses	Method	Result	Reference
H1: Students in the TVLE will outperform their counterparts in the traditional environment	Independent samples *t*-test	Substantiated	Table 4
H2: Students in the TVLE will report higher levels of computer self-efficacy than their counterparts in the traditional environment	Independent samples *t*-test	Substantiated	Table 6
H3: Students in the TVLE will report different degrees of satisfaction than students in the traditional environment	Independent samples *t*-test	Substantiated	Table 6
H4: Students in the TVLE will report higher levels of learning climate than their counterparts in the traditional environment	Independent samples *t*-test	Substantiated	Table 6

TVLE, technology-mediated virtual learning environment.

the TVLE and computer self-efficacy. Students in the TVLE usually spend more time interacting with computers and IT. Thus, the main reason for high computer self-efficacy in the TVLEs is probably not because of the learner control. Instead the high computer self-efficacy is because of the time and interactions that the learners spent. Second, we selected basic computer skills as the subject used in the current study. Because basic computer skills is a subject that highly relates to the using of IT. Replications concerning other subjects seem critical to generalize our results. Finally, the subjects for TVLE and traditional classroom are randomly selected, and the learner's traits and basic knowledge report no difference. Thus, we assume that the learner's self-paced are the same for both TVLE and traditional classroom.

Conclusions and implications

TVLEs offer popular learning environments because of their convenience and flexibility, but their effectiveness remains an open question (Milheim & Martin

1991; Kiser 1999). Drawing on virtual learning environment and technology-mediated learning theory, we developed a conceptual framework that identifies the major dimensions of a TVLE and their relationship with learning effectiveness. We then conducted empirical studies to examine our research framework. We identified four criteria – learning performance (test grades), computer self-efficacy, satisfaction, and learning climate – to represent the effectiveness of a learning environment based on previous research (Vygotsky 1978; Alavi *et al*. 1995; Compeau & Higgins 1995; Williams 1996). Our findings suggest that students learning basic IT skills in TVLEs have better learning effectiveness than their counterparts in traditional classrooms. These findings support the studies conducted by Keller (1983) and Williams (1996), but are not consistent with the argument proposed by Russell (1999) concerning technology-mediated learning.

Our experiment used virtual learning tools that combine audio, video, online interactions with students or instructors, and the connection with instructional material and other learning sites. According to Alavi *et al*'s (1995) research, studies that evaluate learners' behaviour and learning effectiveness in relation to new learning environments must always consider the impact of novelty on the measured criteria. The effect of adopting a new technology may be transitory in nature and not an enduring outcome. Since the effect of learning may because of the novelty of adopting a new technology, our field experiment lasted for 15 weeks to minimize the transitory effects. Because TVLEs provide a high level of learner control, coupled with aids for self-monitoring of progress, the students in the TVLEs outperform their counterparts in the traditional environment. The test scores of students in the TVLEs are higher. In addition, from Table 5, there is no performance difference in TVLEs between mid-term and final, while the performance becomes lower in the traditional environment. This finding indicates that the performance is not because of the transitory effects of novelty. Thus, it is reasonable to suggest that learning in the virtual environment is beneficial from a performance point of view.

TVLEs are the learning environments unfamiliar to most students who need to develop appropriate learning strategies (Jonassen 1985). However, with the help of easy-to-use browse, as well as high quality and reliability of technology, TVLEs may facilitate the gathering of information. An electronic forum in TVLEs with discussion board technology enables rich interactions. Instructors may use it to quickly and publicly answer student questions, and also promote asynchronous discussion. Students may access different knowledge sources to explore a subject, and engage in discourse and construction of meaning. As a result, students may attain both objectivist and constructivist learning model in TVLEs (Colins 1995; Piccoli *et al*. 2001). Based on the theory of motivational instructional design (Keller 1983; Martin & Briggs 1986), we expected high computer self-efficacy from learners because they have more control over the learning in TVLEs environment. Our results show that students in the TVLE have higher computer self-efficacy. This seems to imply that higher learner control leads to higher computer self-efficacy. When students receive considerable guidance and instruction in TVLEs, they feel proud that they have the capability to use learning tools and learn independently. Once students have used the instructional tools in TVLEs and learned independently, they feel that they could do it again in the future. Piccoli *et al*'s (2001) research indicates that learners attribute their successful computer self-efficacy to their own effort and ability.

Subjects in TVLEs reported higher levels of satisfaction than their counterparts in the traditional environment. Our finding is consistent with prior studies regarding learner control and satisfaction (Merrill 1983; Williams 1996). We have explained the positive effects of learner control on satisfaction in the hypothesis development section. We may ascribe this result to the capability of using a novel technology-intensive learning environment by learners who belong to the young generation (age ≤ 13). Most learners were satisfied with the high technology quality and reliability provided by our virtual learning environment. Subjects reported that the access speed was very fast and the interface was user-friendly. The aforementioned explanations seem to suggest that technological proficiency and the ability to rely on the community of learners through learning tools have a positive effect on satisfaction (Brown 1996; Hara & Kling 2000).

Finally, our study supports the hypothesis that the learner's emotional learning climate in the TVLE is

higher than their counterparts in the traditional environment. One implication could be that the students in the TVLE are more willing to join the class because of the novel means of interacting with other students and instructors. TVLEs are open systems that allow for participant interaction through synchronous and asynchronous electronic communication. Because of the available learning and electronic communication tools in the TVLE, students can ask and answer questions, post comments, and participate in a knowledge sharing and exchange with peers and the instructor. As a result, students may have more chance to verbalize and articulate their current understanding. According to Collins's (1991) research, articulation processes facilitate learners to evaluate their understanding by making their decisions and problem solving strategies explicitly. The TVLE provides learners with tools to promote the expression of tacit knowledge and its reinterpretation into explicit knowledge. In addition, learners assess their progress and their instructional needs during self-paced leaning. To summarize, it seems reasonable to assume that the high socio-emotional climate is because of the capability of facilitating group interactions and assisting learners in measuring their progress and instructional needs in our TVLE (Steinberg 1989; Milheim & Martin 1991; Dennis & Valacich 1994).

Our study did not investigate the impact of human dimension – individual traits of students – on learning effectiveness. Since the major difference between TVLEs and traditional classrooms is that the former shifts control and responsibility on the learner, individual characteristics of learners may play a critical role in influencing learning effectiveness. Piccoli *et al*'s (2001) study suggests that the ability to manage time and learning schedule, monitor personal progress, and communicate through electronic media belong to the category of learner' human dimension. We may also examine the influence of computer attitude, computer experience, and course expectation in the future research (Paolucci 1998; MacGregor 1999).

Acknowledgements

We would like to acknowledge the comments from anonymous reviewers who have provided remarkable insights to improve the quality of this paper. This project was partially supported by National Science Council (NSC) of Taiwan and the research centre of Mobile Commerce at NKFUST.

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