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EXAMINING EFFECTS OF TECHNOLOGY-ASSISTED LEARNING ON LEARNING EFFECTIVENESS AND SATISFACTION: A QUASI-EXPERIMENTAL STUDY

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Abstract

Examining students' learning effectiveness and satisfaction is critical to the ultimate success of technology-assisted learning that has been deployed at a fast-growing pace. The accumulated results from prior research are mostly equivocal. Based on how technology-assisted learning may influence students' learning process, we analyze technology-assisted learning and synthesize relevant prior research, and propose a factor model that explains learning effectiveness and satisfaction. We empirically test that model with a quasi-experiment that involves 212 university students, observing their learning of Adobe Photoshop. We test the hypothesized effects of technology-assisted learning and its moderating role in influencing students' learning effectiveness and satisfaction. According to our results, the use of technology-assisted learning adversely affects student engagement. This, in turn, negatively influences their learning effectiveness and satisfaction. Student engagement in learning activities appears to mediate the impact of technology-assisted learning on learning effectiveness. Furthermore, the influence of technology-assisted learning on learning satisfaction is mediated by both student engagement and learning effectiveness. Technology-assisted learning shows no significant moderating effects on learning effectiveness or satisfaction. Our empirical results have several important implications for technology-assisted learning research and practice.

Keywords: Technology-assisted learning, Engagement in learning, Learning process, Learning outcomes.

1 INTRODUCTION

Technology-assisted learning has become increasingly crucial for academic study and corporate training. Motivated by such compelling advantages as geographical reach, learner control, and cost effectiveness in course delivery and management, educational institutions and professional organizations are embracing technology-assisted learning by implementing an expanding array of technology-enabled platforms. The economic value of technology-assisted learning has grown substantially; the U.S. market alone amounted to 17.5 billion dollars in 2007 and the global market is expected to exceed 52.6 billion dollars by 2010 (Global Industry Analysts 2008).

Despite the growing use of technology-assisted learning in different subject areas and widely dispersed geographic locations, substantial concerns remain regarding the learning outcome (Allen & Seaman 2006). For example, previous studies have reported a significantly higher dropout rate in technology-assisted learning than rates common to traditional classroom-based learning (Martinez 2003). With technology-assisted learning, the responsibility of managing the learning tasks and process shifts from the instructor to students; thus, the learning outcome, to some extent, is contingent on individuals' characteristics and motivation (Martens et al. 2004). In effect, researchers have noted the need of increased discipline on the part of students in technology-assisted learning; e.g., Allen & Seaman (2006); McSporry & Young (2001); Martens et al. (2004).

Learning effectiveness and satisfaction represent two fundamental and crucial learning outcomes (Bernard et al. 2004; Eom et al. 2006). In general, learning effectiveness refers to the extent to which a person acquires the focal knowledge or skills delivered through a designated teaching (training) activity (Compeau and Higgins 1995; Hu et al. 2007; Ladyshevky 2004), whereas learning satisfaction entails a person's feeling about and assessment of the overall learning process, experience, and outcome (Hu et al. 2007; Keller 1983; Wang 2003). For sustainable use of technology-assisted learning and satisfactory returns on the investment, educators and researchers must understand the key factors that influence students' learning effectiveness and satisfaction. A handful of studies have compared technology-assisted learning and classroom-based learning; however, the empirical results appear equivocal.

Analyzing how technology-assisted learning influence students' learning process offers a logical lens through which we may reconcile the inconsistent findings reported by prior research. We are thus able to identify the conditions under which the use of technology-assisted learning may be beneficial or disadvantageous to students. In this connection, we consider technology-assisted and face-to-face learning using different media of learning that can affect student engagement, a central aspect of experiential learning (Kolb et al. 1990). Furthermore, technology-assisted learning often involves extensive use of computer technology. Therefore, students' computer self-efficacy can influence their learning effectiveness and subsequent satisfaction.

We examine students' learning effectiveness and satisfaction in technology-assisted learning by focusing on student engagement. By considering both our analysis of technology-assisted learning and relevant prior research, we propose a factor model that explains learning effectiveness and satisfaction. We empirically test that model with a quasi-experiment that involves 212 university students. In addition to testing the hypothesized main effects of technology-assisted learning suggested by the model, our experimental design allows us to explore the moderating role of the learning medium in influencing students' learning effectiveness and satisfaction. According to our results, the use of technology-assisted learning adversely affects student engagement. This in turn negatively influences their learning effectiveness and satisfaction; student engagement in learning activities appears to mediate the impact of technology-assisted learning on learning effectiveness. Furthermore, the influence of technology-assisted learning on learning satisfaction seems mediated by student engagement and learning effectiveness. Technology-assisted learning shows no significant moderating effects on learning effectiveness or satisfaction. Our empirical results have several important implications for technology-assisted learning research and practice that we also discuss.

2 LITERATURE REVIEW AND GAP ANALYSIS

Technology-assisted learning offers an attractive medium for cost-effective learning that can complement classroom-based, face-to-face learning. It provides great reach to geographically dispersed students and can support their interactions, discussions, and synergetic collaborations over distance, through a virtual technology-enabled platform. Supported by technology-assisted learning, students can access the learning materials conveniently on a 24/7 basis, and engage in learning at anytime and from anywhere. These advantages, in conjunction with cost-efficient course delivery and management, are compelling and have created a mounting momentum that propels enthusiastic interests in technology-assisted learning among education institutions and various organizations, public or private (Ladyshevsky 2004; Piccoli et al. 2001; Taylor & Nikolova 2004).

Previous research has studied the outcomes of technology-assisted learning, e.g., Eom et al. (2006), Ladyshevsky (2004), and Piccoli et al. (2001). A common focus is comparing the learning outcomes associated with technology-assisted and face-to-face learning respectively (Ladyshevsky 2004; Piccoli et al. 2001). The accumulated evaluation results seem equivocal, not converged to show the superiority or desirability of technology-assisted learning over face-to-face learning. Bernard et al. (2004) conduct a meta-analysis and suggest that information and communication technology provides a medium for delivering learning materials, and that the use of technology by itself cannot guarantee greater learning effectiveness or satisfaction as compared with conventional, classroom-based learning. This finding implies the importance of other factors that mediate or moderate the effects of technology-assisted learning on students' learning outcomes.

Considerable research has been devoted to identifying key determinants of learning effectiveness or satisfaction; e.g., Eom et al. (2006), and Wang (2003). A host of moderating factors have been investigated; e.g., learning style (Eom et al. 2006; Neuhauser 2002), gender (Taylor & Nikolova 2004), age (Ladyshevsky 2004), intrinsic motivation (Martens et al. 2004), ethnicity (Ladyshevsky 2004). A review of extant literature suggests a lack of agreement regarding the effects of such moderating factors. For example, Eom et al. (2006) show learning style to have significant influences on students' perceived learning outcome and satisfaction in technology-assisted learning. Yet Neuhauser (2002) compares the respective outcomes of technology-assisted and face-to-face learning and reports that learning style has no significant impacts. Similar inconsistent findings have been noted with respect to the influence of gender; e.g., Carlson & Grabowski (1992) and Rovai & Baker (2005). The mixed empirical evidence may have emerged from some common design limitations. Toward that end, Phipps and Merisotis (1999) have raised concerns about the validity and reliability of the instruments used by some prior studies to measure learning effectiveness or satisfaction. For example, some prior research has not duly considered potential confounding factors that are likely to affect or even mask the causality they attempt to establish or test in a technology-assisted learning context (Phipps & Merisotis 1999). As an illustrating point, to study the interaction effects of gender and technology-assisted learning, a simplistic comparison of the relative performance by male and female students in technology-assisted learning is not appropriate. Performance differentials we observe in the experiment may result from other important characteristics inherent to the students or the subject matter rather than from the investigated medium of learning; i.e., technology-assisted learning. Considered together, these limitations suggest the need to use previously validated measurement scales and the inclusion of traditional face-to-face learning as a comparative baseline.

In addition to identifying the important factors affecting students' learning effectiveness and satisfaction directly or indirectly, it is essential to understand how technology-assisted learning affects fundamental aspects of the learning process. Of particular importance is student engagement that can influence their learning effectiveness and satisfaction. By taking such a process view of technology-assisted learning, we can examine *how* students may benefit or suffer from technology-assisted learning, as compared with classroom-based, face-to-face learning. However, few prior studies have examined how technology-assisted learning may affect students' learning process by emphasizing student engagement, mostly qualitatively analyzing the importance of student engagement in technology-assisted learning (e.g., Blass and Davis 2003) and not having a face-to-face control group (e.g., Arbaugh 2000).

Our literature review suggests the need to examine learning effectiveness and satisfaction in technology-assisted learning in regards to the effect on students' learning process by considering key factors that mediate or moderate its effects. To address these gaps, we propose a factor model for explaining students' learning effectiveness and satisfaction, regardless of the learning medium utilized (i.e., technology-assisted or face-to-face). Our model focuses on student engagement and considers the importance of computer self-efficacy. Our design allows the testing of distinct effects of key determinants and hypothesized moderating effects on learning effectiveness and satisfaction. Furthermore, our experimental design allows us to examine the differences in the structural model between these two student groups with adequate statistical techniques; e.g., structural equation modeling. Our study represents an early effort toward using partial least squares (PLS) path modeling in experimental investigations of technology-assisted learning. We randomly assigned subjects into the face-to-face group (i.e., control) and the technology-assisted learning group (i.e., treatment). The overarching objectives of our study are two-fold: (1) examining how technology-assisted learning may affect students' learning effectiveness and satisfaction from the perspective of student engagement in learning activities, and (2) demonstrating how structural equation modeling could be used in experimental studies examining the outcomes of technology-assisted learning.

3 RESEARCH MODEL AND HYPOTHESES

As shown in Figure 1, our model posits that students' learning satisfaction, in a technology-assisted learning setting, is determined by learning effectiveness. Learning effectiveness is influenced by students' computer self-efficacy and engagement in learning activities. According to our model, student engagement is influenced by the medium of learning (i.e., technology-assisted versus face-to-face learning) as well as computer self-efficacy, which plays a less important role in classroom-based, face-to-face learning.

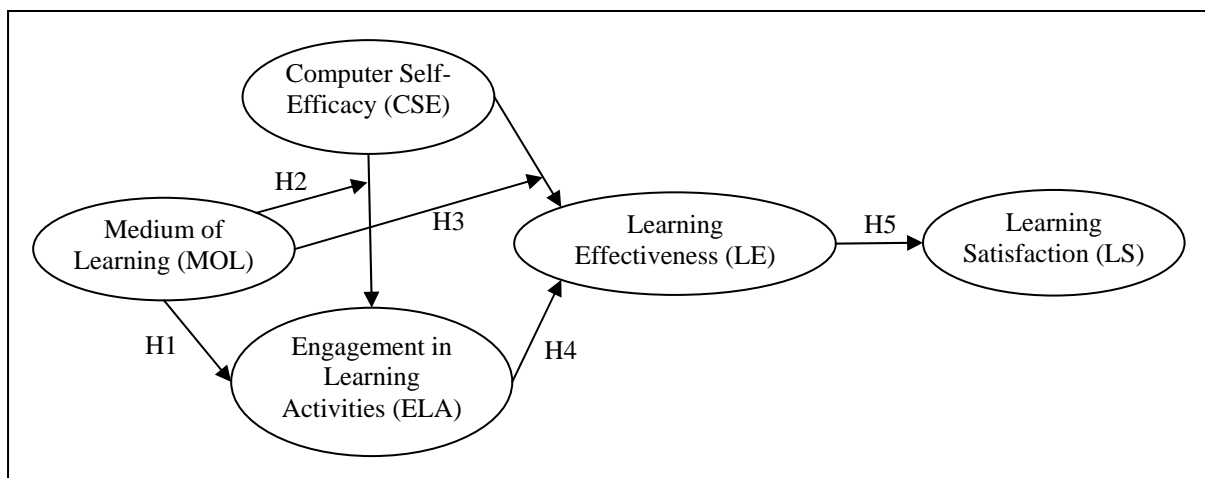


Figure 1. Research Model

Technology-assisted learning offers students with great control over the timing and pace of their learning, the sequencing of learning materials, and the presentation methods (Garrison & Anderson 2003). These features are beneficial to students but demand more responsibilities from students for managing the learning tasks and process (Allen & Searman 2006). Martens et al. (2004) note that not all students are equally motivated and the less motivated ones may fall behind the recommended schedule or have less engagement in learning activities. The shift of responsibility from the instructor to students has been recognized as a central concern in technology-assisted learning (Allen & Searman 2006); when not adequately addressed, this shift can create insurmountable barriers to effective and satisfactory learning by students. Technology-assisted learning is further hindered by the lack of “live” instructions and lecturing, instantaneous real-time peer feedback and support, timely social learning reinforcement, and constructive competitive pressure. As a consequence, students may consider technology-assisted learning ineffective and become less satisfied with their learning. We

thus anticipate students will engage less in technology-assisted learning than in classroom-based, face-to-face learning. Accordingly, we test the following hypothesis:

H1: Students engagement in learning activities is less in technology-assisted learning than in classroom-based, face-to-face learning.

By engaging in learning activities, students actively involve in the learning designed to reinforce or reflect their learning in conditions instrumental to such learning (George 2009). Computer self-efficacy, a person's belief about his or her ability to use computer technology competently (Compeau & Higgins 1995), can impact students' ability and inclination to follow the preprogrammed instructions in technology-assisted learning (Carlson & Grabowski 1992). When using technology-assisted learning, students of higher computer self-efficacy in general are more skillful in using the learning platform than their counterparts of low computer efficacy and thus are likely to engage more in learning activities. Such efficacy has little effects in face-to-face learning, which is primarily delivered by instructors rather than a designated technology-enabled platform. As Spence and Usher (2007) show, computer self-efficacy has a significant influence on students' engagement in technology-assisted learning but its effect is not significant in face-to-face learning. Therefore, we hypothesize the following:

H2: Computer self-efficacy is positively associated with student engagement in technology-assisted learning but not in classroom-based, face-to-face learning.

Computer self-efficacy can affect students' learning effectiveness in technology-assisted learning (Chen 1986, Roca et al. 2006). Students of low computer self-efficacy may have more anxieties and constrained ability to use a computer-based system to complete learning tasks than students of high efficacy (Wilfong 2006). In turn, such anxieties and constrained ability can create adverse effects on students' own assessments of how well they learn with a technology-assisted learning platform. The postulated negative effect of computer-efficacy is not as severe in face-to-face learning, in which technology plays a smaller role in students' learning. We therefore anticipate a positive association between computer self-efficacy and learning effectiveness in technology-assisted learning and hypothesize the following:

H3: Computer self-efficacy is positively associated with students' learning effectiveness in technology-assisted learning but not in classroom-based, face-to-face learning.

Effective learning requires students to proactively engage in the learning activities designed to practice or review what they have learned. According to experiential learning theories (Kolb et al. 1990), students learn by doing. By engaging in learning activities, students can internalize their learning experience and better reflect and absorb that experience. Students who proactively engage in learning activities are more likely to consider their learning effective than those not engaging in such activities, regardless of the medium of learning. Therefore, we posit a positive relationship between student engagement and learning effectiveness in both technology-assisted learning and face-to-face learning; accordingly, we test the following hypothesis:

H4: Student engagement in learning activities is positively associated with learning effectiveness in both technology-assisted and face-to-face learning.

Effective learning leads to learning satisfaction. When students conceive they are successfully acquiring the focal knowledge or skills in an effective and efficient manner, they likely will become satisfied with the learning. In many cases, learning is goal-oriented and focuses on particular knowledge or skills to be obtained by students through a chosen medium of learning and appropriate teaching methods/techniques. Students who perceive successfully achieving the learning goal (e.g., by acquiring the focal knowledge or skills) are likely to exhibit greater satisfaction than their counterparts who fail to achieve the goal, regardless of the medium of learning utilized. We anticipate a positive relationship between learning effectiveness and learning satisfaction and therefore hypothesize the following:

H5: Students' learning effectiveness is positively associated with their learning satisfaction in both technology-assisted and classroom-based, face-to-face learning.

4 STUDY DESIGN AND DATA COLLECTION

We performed a quasi-experiment to examine the effectiveness of and satisfaction in technology-assisted learning, using classroom-based, face-to-face learning as a comparative baseline. In this section, we detail our experimental design, measurements, subjects, experimental tasks, experimental flow, and data collection.

Experimental design. We adopted a one-variable randomized design: half the experimental sessions utilized technology-assisted learning and the remaining employed classroom-based, face-to-face learning. We allowed subjects to freely choose the experimental session to join according to their availability and schedule preference. The learning medium used in each session, technology-assisted or face-to-face, was random and not revealed to subjects at the session sign-up time. Before the experiment, we gathered demographic data from the subjects and analyzed them to ensure subject comparability between groups.

Measurements. We adapted measurement scales developed and validated by prior research, with minor wording changes to fit our context and subjects. We assessed learning effectiveness with students' perceived effectiveness, congruent with the suggestion by Rovai et al. (2003), who advocated the importance of perceived effectiveness in students' learning. Specifically, we adapted items from Hu et al. (2007) to measure learning effectiveness. Items for measuring learning satisfaction were from Wang (2003) and items for computer self-efficacy were from Compeau & Higgins (1995). All question items used a seven-point Likert scale, with 1 being "strongly disagree" and 7 being "strongly agree." To reduce the potential anchoring effect that may induce monotonous responses from subjects, we randomly sequenced the items in the questionnaire¹. In addition, we assessed each subject's engagement in learning activities by the number of optional learning tasks he or she completed during the experiment.

Subjects. We targeted university students' learning Adobe Photoshop, a commercially available graphics editing software package widely used by graphics professionals and amateurs (CNN.com 2007). The choice of this software was made primarily because it is a popular graphics tools among graphics and Web designers, and the knowledge and skills required for the effective use of this software can be delivered through both classroom-based learning and programmed laboratory sessions without extensive "live" instructor-led lecturing and interactions. Compared with tacit knowledge typically difficult to codify and often disseminated through face-to-face learning, the knowledge and skills for using Photoshop are explicit in nature, making this learning appropriate for our purpose. With the assistance of the instructors teaching an introductory information systems course designed for the first-year business students of a major university in Hong Kong, we solicited students for voluntary participation. Through prior course work, our targeted students already had acquired the basic skills in using word processing, spreadsheet applications, and Web page design. Therefore, they had sufficient background knowledge and general skills to learn how to use Photoshop in a classroom-based or a technology-assisted setting. Each subject received fifteen U.S. dollars for his or her time and effort. As many universities have deployed various technology-assisted learning, including the institution in which our study was conducted, our subjects are representative of the general student population commonly targeted for technology-assisted learning.

Experimental tasks. In the experiment, student learned to use Photoshop to add text to images, straighten scanned images, crop images, correct exposure, remove wrinkles, create glamorous looks, and create liquefied distortions, as well as use the Spot Healing Brush and Red Eye Removal tools. With the assistance of several domain experts, we designed appropriate learning exercises and tasks to be included in the experiment. In each experimental session, we presented identical learning materials, delivered through technology-assisted or face-to-face, and provided subjects with exercises to prepare

¹ The specific items used in this study are available on request.

them for completing the tasks in the experiment. All face-to-face sessions were taught and all the technology-assisted sessions were conducted by the same investigator.

Experimental flow and data collection. Our experiment consisted of six sessions conducted in a designated computer lab and administered by the same investigator. At the beginning of each experimental session, we explicitly informed the subjects of the research objectives and addressed any privacy-related questions or concerns. We clearly communicated our intent and commitment to performing data analyses at an aggregate level rather than in any personally identifiable manner, as well as allowing convenient access to the data gathered in the experiment. During the experiment, subjects received the learning materials through classroom-based lecturing (i.e., “live” instructor-led lecturing about these materials, explaining and demonstrating the procedures, answering questions, facilitating the classroom discussions among students) or technology-assisted learning (i.e., students watched a video on computers in the lab, with an instructor in the lab to answer questions and address technical problems). According to our design, subjects in the technology-assisted group received no instructor lecturing and had no “live” discussions with the instructor or peer students. The learning materials for both groups were identical but subjects in the technology-assisted group learned at their own pace. In addition to the experimental tasks, we included additional tasks that subjects could complete at their discretion. After completing the experiment, subjects were asked to fill out a questionnaire designed to collect their self-reported computer self-efficacy, learning effectiveness, and learning satisfaction.

5 ANALYSES, RESULTS, AND DISCUSSIONS

A total of 318 subjects took part in the study, approximately half of the targeted students. We removed 44 subjects who had not completed the questionnaire; among the remaining subjects, 62 indicated that they had used Photoshop occasionally or frequently and therefore were excluded from our analyses. As a result, our effective sample size was 212. We compared the subjects in our sample and those removed from our data analyses (i.e., those did not complete the questionnaire or had used Photoshop previously) and found that they were mostly comparable along the demographic dimensions. In Table 1, we summarize the demographic background of our subjects; the subjects in the technology-assisted group and the face-to-face group were highly comparable. We performed χ^2 tests to ensure no significant between-groups differences in the gender distribution ($p = 0.80$), average computer usage ($p = 0.80$), and average Internet usage ($p = 0.79$).

	Face-to-Face Group	Technology-Assisted Group
Gender	Male: 41 (41%), Female: 59 (59%)	Male: 51 (45.5%), Female: 61 (54.5%)
Average computer usage per week	< 5 hrs: 13 (13%), 5-10 hrs: 26 (26%), 11-15 hrs: 17 (17%), 16-20 hrs: 15 (15%), > 20 hours: 29 (29%)	< 5 hrs: 10 (9%), 5-10 hrs: 20 (18%), 11-15 hrs: 18 (16%), 16-20 hrs: 21 (19%), > 20 hrs: 43 (38%)
Average Internet usage per week	< 5 hrs: 1 (1%), 5-10 hrs: 13 (13%), 11-15 hrs: 26 (26%), 16-20 hrs: 18 (18%), > 20 hrs: 42 (42%)	< 5 hours: 0 (0%), 5-10 hours: 13 (12%), 11-15 hrs: 26 (23%), 16-20 hrs: 20 (18%), > 20 hours: 53 (47%)

Table 1. Summary of Subjects' Demographic Background

Measurement model. We established measurement invariance using LISREL, and analyzed the structural model for each group with Partial Least Squares (PLS) that maximizes the variance explained in the dependent variables and is less demanding on sample size (Chin 1998). We employed the Full Information Maximum Likelihood (FIML) method (Du Toit & Du Toit 2001) to establish measurement invariance between the face-to-face group and technology-assisted groups. We first performed a confirmatory factor for each group and removed the measurement items not loading well in their corresponding latent construct. Then, we assessed the cross validation and factor loadings invariance of the measurement model; items leading to the invariance between the two groups were dropped, consistent with the common multigroup analysis practice in social sciences research (Tsui et al. 2007). In the final model, the composite reliability values of all the investigated constructs in

each group are greater than 0.8, exceeding the suggested minimum requirement of 0.7 (Fornell & Larcker 1981). Furthermore, the average variance extracted (AVE) of each construct exceeds 0.5, a common cutoff value signifying adequate convergent validity (Fornell & Larcker 1981). The square root of the AVE of each construct is greater than the correlations between the construct and other constructs in the model, suggesting appropriate discriminant validity (Fornell & Larcker 1981). Overall, our items show satisfactory reliability and validity in both the face-to-face and technology-assisted learning.

In Table 2, we provide descriptive statistics for the latent variables and student engagement measured by the number of additional learning tasks a subject completed. With the exception of computer self-efficacy, the technology-assisted group has scores significantly lower than those of the face-to-face group. The final measurement model appeared to fit the data collected from each group: face-to-face learning, $\chi^2 = 23.04$, $df = 17$, p -value = 0.15, CFI = 0.98, and RMSEA = 0.06; technology-assisted learning, $\chi^2 = 17.96$, $df = 17$, p -value = 0.40, CFI = 0.99, and RMSEA = 0.02. To test the significance of the mediated effects of the medium of learning, we examined the structural equivalence of our model between the groups, detailed in the following subsection.

	Face-to-Face Group		Technology-Assisted Group		<i>t</i> -tests	
	Mean	S.D.	Mean	S.D.	<i>t</i> -statistic	<i>p</i> -value
CSE	5.00	0.83	4.83	0.89	1.37	0.17
LS	5.48	0.91	5.05	1.06	3.19	0.00
LE	5.26	0.97	4.74	1.15	-3.61	0.00
ELA	7.75	1.82	4.62	2.69	9.78	0.00

Table 2. Descriptive Statistics of Responses from Subjects in Each Experiment Group

We performed cross validation assessment by testing a null hypothesis (H_0) that states the measure identical between the face-to-face group and the technology-assisted group, against the alternative hypothesis (H_1) suggesting the model not identical between the two groups. As we show in Table 3, the large p -value for the χ^2 difference suggests that H_0 cannot be rejected; i.e., the measure was identical to the face-to-face and technology-assisted groups.

	χ^2	d.f.	<i>p</i> -value
H_0	37.23	39	0.55
H_1	25.81	24	0.36
Difference	11.42	15	0.19

Table 3. χ^2 Difference Test for Cross Validation

To assess whether the factor loadings of the measurement model were invariant between the groups, we tested a null hypothesis (H_0) suggesting the factor loadings identical between the face-to-face group and the technology-assisted group, against the alternative hypothesis (H_1) that posits the factor loadings are not identical between the two groups. As shown in Table 4, the large p -value for the χ^2 difference suggests that H_0 cannot be rejected; i.e., the factor loadings were identical across the control and treatment groups.

	χ^2	d.f.	<i>p</i> -value
H_0	26.4	28	0.55
H_1	25.81	24	0.36
Difference	0.59	4	0.19

Table 4. χ^2 Difference Test for Invariance of Factor Loadings

Structural model and hypothesis testing. The establishment of measurement invariance shows the semantic meanings of computer self-efficacy, learning effectiveness, and learning satisfaction

conceived by subjects in both face-to-face and technology-assisted groups to be comparable, if not identical. We analyzed the structural equivalence of our model between the two groups by following the procedure used by Bagozzi et al. (1991): pooling the data for the face-to-face and technology-assisted groups, and creating a dummy variable (i.e., the medium of learning, MOL hereafter) with zero for the face-to-face group and one for the technology-assisted group. This dummy variable was modeled as a predictor in our model, as shown in Figure 2. We then took the product-indicator approach to account for the moderating effects of learning medium (Chin et al. 1996). That is, interaction terms were created by multiplying MOL with the indicators of each predictor; i.e., CSE, ELA, or LE. In Figure 2, we provide a graphical depiction of the resulting model.

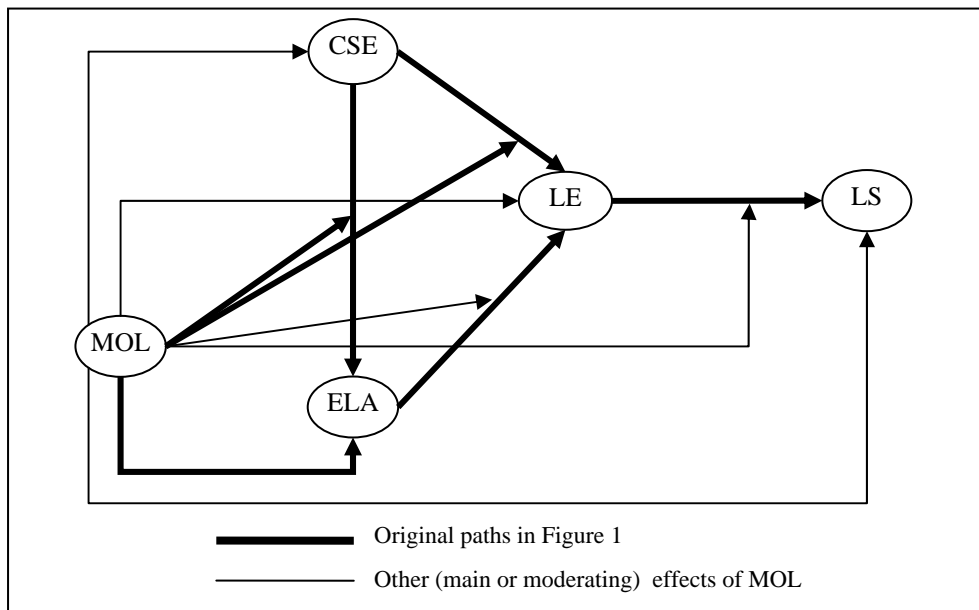


Figure 2. A Model for Testing Main and Moderating Effects of Medium of Learning

We performed a standard bootstrap procedure on 500 sets of samples. In Table 5, we show the standardized path coefficients, *t*-statistics and *p*-values. According to our results, learning medium appears to have no significant moderating effects on the relationship between computer self-efficacy and learning effectiveness, or the relationship between student engagement and learning effectiveness. The moderating effects of learning medium on the relationship between learning effectiveness and learning satisfaction are not significant either. The only significant observed effect of medium of learning is the use of technology-assisted learning in reducing student engagement in learning activities.

Paths	Standardized Path Coefficients	<i>t</i> Statistics	<i>p</i> -value
MOL -> CSE	-0.12	1.57	0.12
MOL -> ELA	-0.99***	3.73	< 0.001
MOL -> LE	0.66	1.63	0.10
MOL -> LS	-0.09	0.34	0.73
CSE -> ELA	0.09	1.12	0.26
CSE * MOL -> ELA	0.43	1.58	0.12
CSE -> LE	0.35***	4.15	< 0.001
CSE * MOL -> LE	-0.34	0.94	0.35
ELA -> LE	0.53**	3.00	< 0.01
ELA * MOL -> LE	-0.30	1.40	0.16
LE -> LS	0.68***	9.13	< 0.001
LE * MOL -> LS	0.03	0.12	0.91

Table 5. Summary of Path Coefficients and Statistic Significance

We removed the insignificant paths and reanalyzed the model. In the final model, ELA is significantly explained by MOL ($\beta = -0.58, p < 0.001$) with $R^2 = 0.34$; LE is significantly explained by CSE ($\beta = 0.28, p < 0.001$) and ELA ($\beta = 0.33, p < 0.001$) with $R^2 = 0.22$; and LS is significantly explained by LE ($\beta = 0.70, p < 0.001$) with $R^2 = 0.49$. Hence, our experimental data support H1, H4 and H5. Subjects in technology-assisted learning exhibit less engagement in learning activities than those in face-to-face learning. Student engagement in learning activities is a significant determinant of learning effectiveness, which has a significant, positive associative with learning satisfaction. Although the learning effectiveness appears lower in technology-assisted learning (see Table 2), the influence of learning medium appears to be mediated by student engagement. Further analysis shows the direct association between technology-assisted learning and learning effectiveness to become statistically insignificant after controlling for student engagement. Similarly, although subjects in technology-assisted learning exhibit lower learning satisfaction (see Table 2), the impact of medium of learning seems to be mediated by both student engagement and learning effectiveness. The direct influence of technology-assisted learning on learning satisfaction appears to be statistically insignificant.

In Table 5, we show that the association between computer self-efficacy and engagement in learning activities is insignificant in both face-to-face and technology-assisted learning. Furthermore, the medium of learning appears to have no significant moderating effects on this relationship. Our analysis suggests computer self-efficacy may be insignificantly associated with engagement in learning activities in technology-assisted learning; not supporting H2. Statistically, it is plausible that this association is significant when we examine the structural model with the data from the technology-assisted learning group alone. This analysis allows us to examine whether the significance is suppressed by the responses of the subjects in face-to-face learning. In Table 6, we summarize the path coefficients and statistical significance of our analysis for the technology-assisted learning and face-to-face learning groups separately.

Paths	Technology-Assisted Learning			Face-to-Face Learning		
	Standardized Path Coefficients	<i>t</i>	<i>p</i>	Standardized Path Coefficients	<i>t</i>	<i>p</i>
CSE -> ELA	0.25*	2.50	0.01	0.09	0.81	0.42
CSE -> LE	0.23*	2.49	0.01	0.39**	3.99	< 0.01
ELA -> LE	0.22*	2.34	0.02	0.35**	2.90	< 0.01
LE -> LS	0.68***	12.16	0.00	0.69***	10.59	< 0.0001

Table 6. Path Coefficients and Statistical Significance for Technology-Assisted Learning Group

As shown, computer self-efficacy is significantly associated with student engagement in the technology-assisted learning group but not so in the face-to-face learning group. Hence, our experimental data seem to provide scant support for H2. With H3, we hypothesize computer self-efficacy to be positively associated with learning effectiveness in technology-assisted learning, but not in face-to-face learning. However, results in Table 6 are consistent with those in Table 5, showing a significant positive association between computer self-efficacy and learning effectiveness in both face-to-face and technology-assisted groups. This result may be partly explained by our subject matter choice; i.e., Photoshop, a popular graphics editing application. It is likely that subjects of high computer self-efficacy may be able to learn new application software more effectively than those of low computer efficacy, regardless of the particular medium of learning utilized. In this light, this finding may not be generalizable across different subject matters.

Discussion. As shown in Table 2, student engagement, learning effectiveness, and learning satisfaction are all significantly lower in technology-assisted learning than in face-to-face learning. Our PLS analysis suggests that technology-assisted learning has a significant, direct effect on student engagement only; its impacts on learning effectiveness seem to be mediated by student engagement and its influence on learning satisfaction appears to be mediated by both student engagement and learning effectiveness. As a result, we only note a significant effect on student engagement. Medium

of learning by itself does not lead to higher or lower learning effectiveness or satisfaction, a finding consistent with the suggestion by Clark (1994). We can reduce the adverse impacts on students' learning effectiveness and satisfaction by designing technology-assisted learning systems capable of engaging students more in the learning activities; e.g., improved instructional design (Concannon et al. 2005), online chats (Angelino et al. 2007), games (Pivec & Dziabenko 2004), and "virtual mentors" (Zhang 2004).

Our results also suggest that technology-assisted learning has a weak moderating effect on learning effectiveness and satisfaction. As shown in Table 5, technology-assisted learning may not significantly change the nature of relationships between student engagement and learning effectiveness, or that between student engagement and learning satisfaction. The only notable moderating effect we observed is between computer self-efficacy and student engagement in technology-assisted learning. As shown in Table 6, computer self-efficacy is positively associated with student engagement in the technology-assisted learning group but not in the face-to-face learning group. This moderating effect becomes insignificant statistically after controlling for other factors, as we show in Table 5. Nonetheless, it is important to note that technology-assisted learning can unintentionally put students of low computer-self efficacy in a disadvantageous position as they likely will engage less in online learning activities, as compared with their counterparts of high self-efficacy. By engaging less in learning activities, students will suffer in both learning effectiveness and satisfaction. Cautionary measures should be taken to better orient, prepare and facilitate students to use technology-assisted learning to avoid putting them in such disadvantaged positions (Angelino et al. 2007; Chen 1986).

Our findings highlight the need for researchers to move beyond comparing the outcomes in face-to-face and technology-assisted learning settings. Continued research is needed to further scrutinize the relationship between students' learning process and the medium of learning utilized. Technology-assisted learning may have important equality implications. For example, our results suggest that the engagement, learning effectiveness, and satisfaction associated with technology-assisted learning seem vary among students because of their difference in computer self-efficacy. Based on our results, we also provide some guidelines on how to improve student engagement through technology-assisted learning system design and instructional strategies.

6 CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Our study makes use of statistically validated instruments and partial least squares (PLS) modeling to examine students' learning of Photoshop with data collected from a quasi-experiment. We test the main effects and the moderating effects of technology-assisted learning. According to our results, technology-assisted learning has a significant main effect on student engagement; but, its effect on learning effectiveness seems mediated by student engagement and its impact on learning satisfaction appears to be mediated by both student engagement and learning effectiveness.

We contribute to the extant technology-assisted learning literature by examining the nature of the technology-assisted learning's influences on learning effectiveness and satisfaction. Our findings show that technology-assisted learning is not the panacea for limitations commonly found in traditional, face-to-face learning, nor it is inherently inferior to face-to-face learning, as some study results imply (Wyman 2007). From a research perspective, it is important to understand *how* technology-assisted learning can be used to enhance students' learning experience. Our experimental results show that we can improve students' learning effectiveness and satisfaction in technology-assisted learning by designing systems or using teaching strategies that encourage, facilitate, and reward their engagement in online learning activities.

This study represents a point of departure for future investigations of the effects of technology-assisted learning on students' learning experience. These findings advance our understanding of the benefits and constraints of technology-assisted learning as well as enhancing the design and selection of technology-assisted learning systems. Several areas are important and warrant our investigative attention. First, our study finds that computer self-efficacy is positively associated with learning effectiveness, regardless of the medium of learning. The insignificant moderating effect between

computer self-efficacy and learning medium on learning effectiveness may be partly due to our choice of the subject matter; i.e., computer application software. Future research should examine whether this relationship exists in other subject matters. Second, further controls in PLS path modeling and quasi-experiment can be explored to provide insights and probable explanations for the inconsistent results regarding the effects of gender, learning style, or other individual characteristics. Last but not least, future research should be conducted to analyze and empirically test different motivation-boosting strategies for increasing student engagement in technology-assisted learning.

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