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# 6. IS TECHNOLOGY-MEDIATED LEARNING MADE EQUAL FOR ALL? EXAMINING THE INFLUENCES OF GENDER AND LEARNING STYLE

ABSTRACT

The current research investigates the equality of students' learning outcomes in technology-mediated learning. We study important individual differences and focus on the influences of gender and learning style. We perform two experimental studies that employ methodologically rigorous designs, multiple learning outcome measures, and previously validated measurement scales. Specifically, we examine learning effectiveness, perceived learnability, and learning satisfaction in technology-mediated learning, using classroom-based face-to-face learning as a comparative baseline. Our investigations address some limitations commonly found in many prior studies, including instrument reliability and confounding factors. Overall, our findings suggest that students benefit from technology-mediated learning differently, dependent on their gender. For example, female students consider technology-mediated learning more effective and satisfactory than male students, but their learning motivation is significantly lower than that of their male counterparts. Learning style also matters, perhaps to a lesser extent. Students who rely more on concrete experience, as opposed to abstract conceptualization, find the course materials delivered through technology-mediated learning more difficult to learn. Our findings have several implications for research and practice, which are discussed.

## INTRODUCTION

The Internet has become a salient, worldwide education platform. According to Global Industry Analysts (2008), the technology-mediated learning market in the U.S. alone amounted to 17.5 billion dollars in 2007 and the global market is expected to exceed 52.6 billion dollars by 2010. Internet-based education provides a greater geographical reach and increased learner control with substantially enhanced cost-effectiveness. Advocates also believe that technology-mediated learning has the potential to tailor to individuals' learning needs through adaptive hypermedia (De Bra, Brusilovsky, & Conejo, 2002), personalization (Carchiolo, Longheu, Malgeri, & Mangioni, 2003), and Web 2.0 technologies (Rosen, 2006). Technology-mediated learning has been shown to facilitate digital inclusion by delivering education to social groups generally considered disadvantaged or underprivileged in a conventional,

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classroom-based learning setting; e.g., people living in areas not adequately supported by the existing educational infrastructure (Li & Qi, 2008).

Many studies have examined the effectiveness of technology-mediated learning, with a common emphasis on comparing technology-mediated learning and classroom-based, face-to-face learning. Inconsistent results are reported. Several meta-analysis studies show technology-mediated learning not significantly different from face-to-face learning in terms of learning effectiveness (Bernard, Abrami, Lou, Borokhovski, Wade, & Wozney 2004) or learning satisfaction (Allen Bourhis, Burrel, & Mabry, 2002). The "no significant difference" phenomenon can be viewed as supporting the use of technology-mediated learning as a viable alternative to face-to-face learning (Ubell, 2000). Collectively, however, these evidences show that students may not learn with equal efficiency in a technology-mediated learning environment. Several researchers have specifically cautioned against the equality implications in technology-mediated learning; e.g., Hills (2003), Hvorecky (2004), Manochehr (2006), Khan (2005).

Hvorecky (2004) argues that technology-mediated learning requires great self-discipline and self-motivation from students; therefore, it may not be equally appropriate for every student. According to Arbaugh (2000), female students tend to participate more in online discussions than male students. Manochehr (2006) reports that learning style may not impact students' learning effectiveness in conventional classroom-based learning, but can have significant influences in technology-mediated learning. The concerns about important equality implications in technology-mediated learning demand proper considerations. The effectiveness of learning is influenced by personal variables; e.g., individual student preferences in the design and evaluation of courses delivered through a technology-enabled platform completely or partially (Hills, 2003; Khan, 2005).

Although technology-mediated learning may help to mitigate social inequality through digital inclusion, the influences of individual differences (e.g., gender, learning style) on students' learning effectiveness or outcome warrant further investigation. This chapter explores the learning equality in technology-mediated education by examining the influences of two of the most studied individual factors in education research – gender and learning style – on students' learning effectiveness, perceived course 'learnability', and learning satisfaction in a technology-mediated learning environment, using face-to-face learning as a comparative baseline. We conducted two empirical studies: one focusing on the gender influences in students' learning of Photoshop and another targeting the impacts of learning style in students' learning of English as a foreign language. Overall, our results show that the benefits of technology-mediated learning seem to vary with gender and learning style. Our findings have important implications for research and practice, and can shed light on the future use of technology-mediated learning to foster desirable equality in education.

The remainder of the chapter is organized as follows. Section 2 reviews prior technology-mediated learning research in general and specifically the effects of gender and learning style. In Section 3, we develop our hypotheses. Section 4 describes our study designs and data collections. In Section 5, we describe our data analyses, highlight important results and discuss their implications. We conclude the chapter in Section 6 with a summary and several future research directions.

## LITERATURE REVIEW

In spite of its profound social and political implications, the equality in technology-mediated learning has received little research attention. Digital divide is essential and has been studied from different perspectives, including information technology (e.g., Strover 1999), intention to use a technology (Lam & Lee, 2006; Hsieh, Rai, & Keil, 2008), and general technology skills (Hargittai, 2002). A handful of studies examine the relationship between technology-mediated learning and digital divide. For example, Chen (1986) investigates how digital divide affects the learning effectiveness of different student groups in technology-mediated learning. Chen reports that female students may be disadvantaged in technology-mediated learning because of their relatively lower computer self-efficacy and technology usage. Meyers, Bennett, and Lysaght (2004) investigate adult women in rural areas and their experiences in technology-mediated learning, suggesting several strategies for making technology-mediated learning more equitable. Li and Qi (2008) analyze the use of technology-mediated learning for delivering education to rural areas in mainland China. From a research perspective, the learning equality in technology-mediated learning is important and may be influenced by individual differences or characteristics, which however have not yet received much research attention.

Previous studies examine the impact of several individual differences in technology-mediated learning, without any explicit focus on learning equality; e.g., Arbaugh (2000), Manochehr (2006). The collective findings can be commonly characterized as inconsistent or even contradictory. Consider gender, for example. Keasar, Baruch, and Grobgeld-Dahan (2005) examine technology-mediated learning in science education and report no significant gender effects on students' learning of biology. On the contrary, McSporran and Young (2001) note that technology-mediated learning shifts substantial responsibilities from the instructor to students. They argue that female students tend to be more effective in time management and show empirically that female students learn more effectively in a technology-mediated environment than their male counterparts. Analysis of previous research results seemingly suggests that, in technology-mediated learning, differential learning effectiveness is observed among students with versus without certain characteristics.

To the point, gender is important and has key implications to issues surrounding diversity and equal opportunity. Thus, understanding the gender effect on students' learning is crucial as it allows system developers and instructors to better design technology-mediated learning systems and courses by properly addressing the key barriers commonly experienced by students of the disadvantaged gender. As Crew and Butterfield (2003) note, the use of technology-mediated learning, if adequately designed, may allow female students to learn more effectively in computer programming, a subject area that historically attracted less interest from female students (Bombardieri, 2005).

Learning style is also important, although its significance in technology-mediated learning is not well understood. People have different preferences in how they perceive, acquire or process information, and obtain knowledge (Kolb, Rubin, & Osland, 1990). Conventional classroom-based teaching typically delivers information (knowledge) in a one-to-many fashion, thus making it difficult to accommodate each student's individual needs or preferences. According to Bielawski and Metcalf (2002), technology-mediated learning offers increased flexibility and learner control; therefore, it may be able to better support or facilitate individualized learning, as compared with classroom-based face-to-face learning. Manochehr (2006) shows learning style to have no significant influence on students' learning effectiveness in a conventional instructor-centric learning environment; however, its effects are far more significant in technology-mediated learning. These findings suggest undesirable learning inequality in technology-mediated learning; i.e., not all students learn equally effective in technology-mediated learning. On the contrary, Neuhauser (2002) reports insignificant effects of learning style in technology-mediated learning. It is important to further examine whether students of different genders and/or different learning styles can benefit equally from technology-mediated learning.

Considerable previous research compares students' learning effectiveness in technology-mediated learning and classroom-based, face-to-face learning environments; the findings are mixed at best. For example, Alavi, Wheeler, and Valacich (1995) and Piccoli, Ahmad, and Ives (2001) report no significant differences in students' learning effectiveness in technology-mediated versus face-to-face learning. However, Beerman (1996) shows the use of technology-mediated learning to improve students' learning achievement and learning satisfaction significantly. Analysis of the prior research and inconsistent results points to several plausible explanations. First, many previous studies target various learning outcomes and use different measurements. For example, Alavi (1994) measures learning effectiveness by examining the degree to which a learning process is characterized by three essential learning aspects: active learning and construction of knowledge, co-operation and teamwork in learning, and learning through problem solving. Gardner, Simmons, and Simpson (1992) measure learning effectiveness using students' attitudes toward a course subject. Clements (1991) examines learning effectiveness on the basis of the level of creativity students demonstrate. The use of different measurements makes direct comparisons of the reported results difficult. Second, the instrument used to evaluate a focal learning outcome may have questionable validity or reliability (Phipps & Merisotis, 1999). Third, many studies examining the effects or moderating effects of individual differences on students' learning effectiveness or outcomes adopt a "one-shot design" and do not include an adequate comparative baseline or control group; e.g., face-to-face learning (Phipps & Merisotis, 1999).

This research attempts to reconcile the inconsistent results in the extant literature by addressing several limitations commonly found in prior studies. Specifically, we re-examine the potential inequality in technology-mediated learning by using methodologically rigorous study designs, statistically validated instruments to measure learning effectiveness or outcomes, and including classroom-based, face-to-face learning for control purposes. Academic performance is not the sole purpose of students' learning (Hirschheim, 2005); as a result, we incorporate multiple outcome measures in our studies, including learning effectiveness, perceived learnability, perceived learning community support, learning motivation, and learning satisfaction.

Our foremost goal is to analyze and compare, in technology-mediated learning, the learning effectiveness and outcomes among students who differ in gender or learning style. Our findings shed light on how to better design technology-mediated learning systems and how to better deliver courses using technology-mediated learning so as to foster desirable learning equality among students, despite their differences in gender or learning style.

## HYPOTHESES DEVELOPMENT

### *Technology-Mediated Learning and Gender*

Intrinsic gender-based differences have been observed in conventional classroom-based settings. For example, female students tend to perform better than male students in subjects related to language or social science; male students often outperform female students in mathematics and science. Prior research in neurosciences also shows several fundamental yet intriguing differences between genders in sensation and perception development (Sax, 2006). In our case, if the design of a technology-mediated learning system or a course using such systems fails to consider these differences, the disparity between genders is likely to propel and widen. Each gender has advantages and disadvantages in technology-mediated learning. For example, female students are more disciplined and therefore may learn more effectively in technology-mediated learning than male students (McSporran & Young, 2001). Female students, however, tend to exhibit less positive attitudes toward computer technology and thus may prefer less technology in their learning than male students (Katz, 2006). A review of previous research suggests important gender differences in technology-mediated learning; e.g., Arbaugh (2000), Li (2006).

According to cognitive learning theory, learning is an active, constructive and goal-oriented process (Shuell, 1986; Wittrock, 1978, 1986; Alavi, 1994). In this light, learning outcomes and experience are crucial. We focus on several learning outcome measures: perceived learning effectiveness, perceived learnability, learning motivation, and learning satisfaction. Specifically, perceived learning effectiveness refers to the extent to which a student considers his or learning supported by a medium for learning (e.g., technology-mediated or face-to-face) to be effective for acquiring the information (knowledge) delivered through that medium (Hu, Hui, Clark and Tam, 2007). Perceived learnability denotes the extent to which a student considers the presented learning materials learnable (Hu et al., 2007). Learning motivation refers to the degree to which a student is motivated to make extra efforts towards achieving the learning objectives (Ruohotie, 2000). Learning satisfaction manifests as a student's overall positive assessment of his or her learning experience (Keller, 1983). We test the following hypotheses:

H1: There exists a significant between-gender difference in the perceived learning effectiveness among students supported by technology-mediated learning versus by classroom-based, face-to-face learning.

H2: There exists a significant between-gender difference in the perceived learnability among students supported by technology-mediated learning versus by classroom-based, face-to-face learning.

H3: There exists a significant between-gender difference in the learning motivation among students supported by technology-mediated learning versus by classroom-based, face-to-face learning.

H4: There exists a significant between-gender difference in the learning satisfaction among students supported by technology-mediated learning versus by classroom-based, face-to-face learning.

*Technology-Mediated Learning and Learning Style*

Learning style refers to the important characteristic behaviors of an individual, which can serve as a relatively stable indicator of how he or she perceives, interacts with, and responds to a learning environment (Kolb et al., 1990). Technology-mediated learning has the potential to provide learning tailored to individual students' needs or preferences, through effective use of adaptive multimedia and increased learner control in terms of the pace, time, or location (Bielawski & Metcalf, 2002). Previous research fails to consistently and convincingly prove that students with different learning styles can equally benefit from technology-mediated learning. Our literature review shows many prior studies use instruments with questionable reliability, or do not include face-to-face learning for control purposes, making it difficult to rule out the potential confounding effects of some interacting (conflicting) factors (Phipps & Merisotis, 1999). To address these limitations, we employ validated instruments to measure learning outcomes and include classroom-based, face-to-face learning as a baseline for comparison (control) purposes.

Our dependent variables are objective and perceived learning effectiveness, perceived course learnability, perceived learning community support, and learning satisfaction. In the English learning context, perceived learning effectiveness measures the extent to which a student believes he or she has achieved learning objectives of the course. We use tests designed by experienced English language teachers to objectively measure students learning effectiveness. Learning satisfaction here has the same meaning as in the Photoshop study; it measures a student's overall positive assessment of his or her learning experience (Keller, 1983). Perceived course learnability is similar to perceived learnability in the Photoshop study, except that it is about students' perception of the learnability of materials for the entire course in contrast to just a lab session. We analyze students' perception of the learning community support in technology-mediated or face-to-face learning, which denotes the extent to which a student perceives that the learning environment creates an active, strongly bonded community facilitating and fostering experience exchange and knowledge sharing among peers and their instructors (Hu et al., 2007). We include perceived learning community support in the English study because the study lasted for an entire semester and perceived learning community support has been shown to be an important determinant of learning satisfaction (Wang, 2003).

We use Kolb's Learning Style Model to assess students' learning style and investigate its influences on the learning equality in technology-mediated learning.

Experiential learning represents a core premise of this model, which explores the nature of an individual's learning through experience, reflection, conceptualization, and active experimentation (Kolb et al., 1990). As depicted in Figure 1, a student's learning style can be described on the basis of the relative importance of abstract conceptualization versus concrete experience for perceiving and acquiring information, as well as reflective observation versus active experimentation for processing and assimilating information.

The information perceiving and acquisition by an individual can be experiential (e.g., through senses or feelings) in some "concrete" way (i.e., concrete experience), or through abstract conceptualization (i.e., "meta-level" comprehension) underpinned by formal logic, reasoning, analogy, or metaphor. Concrete experience emphasizes "being involved" and typically deals with immediate human situations in a "live" experiential manner. In contrast, abstract conceptualization focuses on logics, concepts, intuitions, or patterns, placing great value on conceptualization of a higher order, through reflection and internalization. When learning, a student can engage in both concrete experience and abstract conceptualization simultaneously, but may show a noticeable tendency of preferring one over the other. Similarly, students also differ considerably in the way they process information: some prefer active experimentations that focuses on "doing" and others prefer reflective observations that emphasizes "watching." Again, when learning, students often rely on both active experimentation and reflective observation simultaneously; they may, however, exhibit notable preferences for one in a specific learning scenario or task.

Many existing technology-mediated learning systems offer limited support of "live" activities in students' learning (Hamilton & Cherniavsky, 2006). As described, students who primarily learn through concrete experiences tend to value active participations by themselves, peers, and instructors. Such participation-oriented learning demands substantial support of simultaneous interactions and live feedback that are generally better supported by classroom-based, face-to-face learning than by technology-mediated learning. On the other hand, abstract thinkers usually prefer working individually and have a tendency of placing less value on live or group-based participation-oriented learning activities. They might be more tolerant of a learning environment offering limited simultaneous interaction support or live feedback. Therefore, we test the following hypotheses:

H5: In technology-mediated learning, students who are abstract thinkers exhibit higher objective learning effectiveness than do those who are concrete thinkers.

H6: In technology-mediated learning, students who are abstract thinkers perceive greater learning effectiveness than do those who are concrete thinkers.

H7: In technology-mediated learning, students who are abstract thinkers perceive the overall course more learnable than do those who are concrete thinkers.

H8: In technology-mediated learning, students who are abstract thinkers consider the learning community support to be stronger than do those who are concrete thinkers.

H9: In technology-mediated learning, students who are abstract thinkers show higher learning satisfaction than do those who are concrete thinkers.

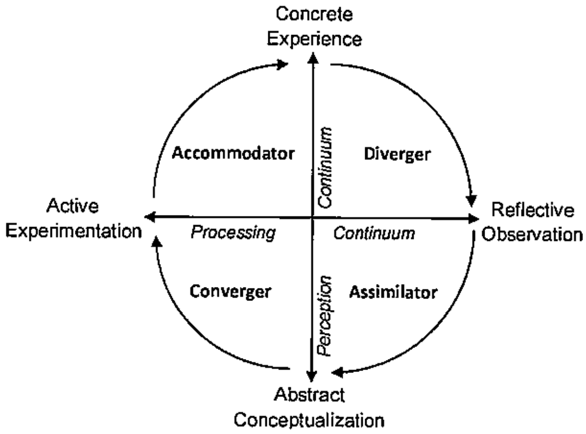


*Figure 1. Kolb's learning style model (Kolb et al., 1990).*

## STUDY DESIGN AND DATA COLLECTION

### *Study 1: Technology-Mediated Learning and Gender*

To examine the influences of gender, we conducted a controlled experiment on students learning Photoshop for Web content publishing. Our experiment consisted of 6 sessions, all conducted in a designated computer laboratory and administered by the same investigator. Half of the sessions used technology-mediated learning and the remaining employed classroom-based, face-to-face learning. Each subject could choose freely which experiment session to join but did not know beforehand whether that session would involve technology-mediated or face-to-face learning. We recruited subjects from undergraduate students taking an introductory Information Systems course in a major English-speaking university in Hong Kong. The Hong Kong government has long recognized the importance of information technology for supporting and fostering learner-centric learning. In the past decade, substantial resources have been allocated to create (upgrade) the IT infrastructure and improve the technical support in various education institutions, leading to evident, significant improvements in computer access and Internet connectivity (Plomp, Anderson, & Law 2009). As a result, our subjects in general are familiar with IT and feel comfortable learning through an electronic medium.

The specific Photoshop topics included in our study were: adding text to images, straightening scanned images, cropping images, correcting exposure, using the Spot Healing Brush, using the Red Eye Removal tool, removing wrinkles, creating a glamour look, and applying liquefied distortion. We designed experimental tasks pertinent to these topics and included some additional, similar tasks to be completed by subjects if they were motivated to do so. We maintained the necessary symmetry across all the sessions; e.g., using the identical learning materials, following the same experiment procedure, utilizing the same warm-up tasks and experimental tasks, and providing all subjects with the same amount of time sufficient for their completing the additional tasks if they chose to do so.

We gathered subjects' demographic information and computer self-efficacy (Compeau & Higgins, 1995) before the experiment. We asked each subject to complete all the experimental tasks and used a post-experiment survey to collect their assessment of perceived learning effectiveness, learnability, learning community support and satisfaction. We also recorded the number of additional tasks a subject completed in the experiment and used it as a proxy for learning motivation. Latent constructs were operationalized using measurement items based on a seven-point Likert scale, with 1 being "strongly disagree" and 7 being "strongly agree." To reduce potential anchoring or floor (ceiling) effects, we randomly sequenced the question items in the questionnaire. The instruments used to measure our latent constructs are presented in the Appendix.

*Technology-Mediated Learning and Learning Style*

To examine the effects of learning style, we performed a longitudinal field experiment on students' learning English as a foreign language. Our subjects were freshmen who enrolled in a freshman English class offered in multiple sections. Each section used either classroom-based, face-to-face learning solely (i.e., the control group) or a balanced combination of technology-mediated and face-to-face learning (i.e., the treatment group), consistent with the salient blended approach to technology-mediated learning (Masie, 2002). Each subject was randomly assigned to a treatment or control session according to his or her class schedule availability. The use of the designated course Web site was mandatory for subjects in the technology-mediated group. This site contained programmed multimedia course materials, including online instructions, exercises, illustrations, and diagnostic feedback, which target different fundamental aspects of English learning. Our study Web site resembles many existing Web-based learning sites and offers limited support of spontaneous interactions, live feedback, and learning community building. Students in the face-to-face group met in the classroom twice as often as their counterparts supported by technology-mediated learning but had no access to the course Web site.

We collected data at the beginning and the end of a 15-week semester. One week before the study, each subject took an online English test to provide a baseline for our objective learning effectiveness assessments. Subjects took another test, also online, at the end of the study (semester). We used the difference between the two test scores to measure each subject's objective learning effectiveness. We gathered subjects' demographic information and assessed their learning style (i.e., abstract conceptualization versus concrete experience, and reflective observation versus active experimentation) within the first two weeks of our study. At the end of the 15-week study, we collected from each subject his or her assessment of perceived learning effectiveness, perceived course learnability, learning community support, and learning satisfaction. All question items employed a seven-point Likert scale, with 1 being "strongly disagree" and 7 being "strongly agree". We randomly sequenced the items in the questionnaire. These question items are presented in the Appendix.

## DATA ANALYSES AND RESULTS

### *Study 1 – Technology-Mediated Learning and Gender*

A total of 326 subjects voluntarily participated in the study, representing approximately half of the targeted student population. We removed responses by 17 subjects who did not complete the questionnaire; as a result, our sample consists of 309 subjects. Students in technology-mediated and face-to-face learning groups were highly comparable in demographics, computer self-efficacy, and average Internet usage, as shown in Table 1.

*Table 1. Summary of demographics in photoshop study*

| | *Face-to-face group* | *Technology-mediated group* |
|---|---|---|
| Gender | Male: 41 (41%)<br>Female: 59 (59%) | Male: 51 (45.5%)<br>Female: 61 (54.5%) |
| Average computer usage per week | < 5 hours: 13 (13%)<br>5–10 hours: 26 (26%)<br>11–15 hours: 17 (17%)<br>16–20 hours: 15 (15%)<br>> 20 hours: 29 (29%) | < 5 hours: 10 (8.9%)<br>5–10 hours: 20 (17.9%)<br>11–15 hours: 18 (16.1%)<br>16–20 hours: 21 (18.8%)<br>> 20 hours: 43 (38.4%) |
| Average Internet usage per week | < 5 hours: 1 (1%)<br>5–10 hours: 13 (13%)<br>11–15 hours: 26 (26%)<br>16–20 hours: 18 (18%)<br>> 20 hours: 42 (42%) | < 5 hours: 0 (0%)<br>5–10 hours: 13 (11.6%)<br>11–15 hours: 26 (23.2%)<br>16–20 hours: 20 (17.9%)<br>> 20 hours: 53 (47.3%) |
| Computer Self-Efficacy | Mean: 5.39<br>S.D.: 0.83 | Mean: 5.42<br>S.D.: 0.85 |

All the constructs show a reasonably satisfactory Cronbach's alpha value (Nunnally 1978): 0.62 for perceived learning effectiveness, 0.69 for perceived learnability, and 0.77 for learning satisfaction. We examine our instruments' convergent and divergent validity by performing an exploratory factor analysis. As shown in Table 2, items that measure the same construct exhibit substantially higher loadings than do those measuring other constructs. The eigenvalue of each extracted factor exceeds 1.0, a common threshold used by previous research (Kim & Mueller, 1978). Overall, our instruments exhibit adequate reliability and convergent/discriminant validity.

To test the main effects of technology-mediated learning and its interaction with gender, we performed a two-way analysis of covariance (ANCOVA), using computer self-efficacy as the covariate. Table 3A summarizes our hypothesis testing results. Regarding the main effects of technology-mediated learning, students using face-to-face learning completed more tasks ($p < 0.01$), perceived greater learning effectiveness ($p < 0.01$), and showed higher learning satisfactions ($p < 0.01$) than their counterparts supported by technology-mediated learning. We observe a significant interaction effect of technology-mediated learning and gender on students'

*Table 2. Analysis of convergent and discriminant validity for latent constructs in photoshop study*

| *Question Items* | *Components extracted* | | | |
|---|---|---|---|---|
| | *Factor 1* | *Factor 2* | *Factor 3* | *Factor 4* |
| Computer self-efficacy (CSE-1) | **0.80** | 0.10 | 0.09 | 0.03 |
| Computer self-efficacy (CSE-2) | **0.78** | 0.04 | -0.03 | -0.02 |
| Computer self-efficacy (CSE-3) | **0.80** | 0.04 | 0.02 | -0.04 |
| Computer self-efficacy (CSE-4) | **0.68** | 0.09 | 0.05 | 0.18 |
| Learning satisfaction (LS-1) | 0.071 | **0.79** | -0.11 | 0.14 |
| Learning satisfaction (LS-2) | 0.17 | **0.78** | 0.15 | -0.01 |
| Learning satisfaction (LS-3) | 0.00 | **0.66** | 0.01 | 0.32 |
| Perceived learnability (PL-1) | -0.01 | -0.04 | **0.88** | 0.07 |
| Perceived learnability (PL-2) | 0.02 | -0.12 | **0.85** | -0.05 |
| Perceived learnability (PL-3) | 0.09 | 0.19 | **0.60** | -0.05 |
| Perceived learning effectiveness (PLE-1) | -0.12 | 0.10 | 0.01 | **0.81** |
| Perceived learning effectiveness (PLE-2) | 0.16 | 0.10 | -0.05 | **0.72** |
| Perceived learning effectiveness (PLE-3) | 0.12 | 0.49 | 0.01 | **0.63** |
| Eigenvalue | 3.08 | 2.16 | 1.8 | 1.05 |
| Percent variance explained | 23.71 | 16.61 | 14.01 | 8.07 |

learning motivation measured by the number of additional learning tasks completed by a student ($p < 0.01$). We find a similar, significant interaction effect on perceived learning effectiveness ($p < 0.05$) as well as on learning satisfaction ($p < 0.05$), shown in Table 3A. Gender by itself does not seem to affect perceived learning effectiveness, perceived learnability, learning motivation, or learning satisfaction significantly.

In Table 3B, we summarize the mean of each dependent variable observed in the respective groups (i.e., technology-mediated or face-to-face) and gender. As shown,

*Table 3A. ANCOVA analysis results for photoshop study*

| *Dependent variables* | *Sig.* | | | |
|---|---|---|---|---|
| | *Computer self- efficacy* | *Technology-mediated learning* | *Gender* | *Technology-mediated learning × gender* |
| Learning Motivation (LM) | 0.31 | < 0.01** | 0.07 | < 0.01** |
| Learning Satisfaction (LS) | < 0.01** | < 0.01** | 0.085 | 0.05* |
| Perceived Learnability (PL) | 0.24 | 0.56 | 0.84 | 0.88 |
| Perceived Learning Effectiveness (PLE) | 0.12 | < 0.01** | 0.37 | 0.05* |

* Significant at 0.05 level. ** Significant at 0.01 level.

*Table 3B. A Comparison of descriptive statistics for photoshop study*

| *Variables* | *Mean (S.D.)* | | | |
|---|---|---|---|---|
| | *Face-to-face learning* | | *Technology-mediated learning* | |
| | *Male* | *Female* | *Male* | *Female* |
| Learning Motivation (LM) | 7.71 (1.89) | 8.06 (1.67) | 5.44 (3.05) | 4.07 (2.70) |
| Learning Satisfaction (LS) | 5.50 (0.71) | 5.52 (0.79) | 4.82 (1.16) | 5.21 (0.90) |
| Perceived Learnability (PL) | 4.67 (0.94) | 4.62 (0.93) | 4.73 (1.08) | 4.70 (1.03) |
| Perceived Learning Effectiveness (PLE) | 5.21 (0.82) | 5.13 (0.94) | 4.46 (1.20) | 4.80 (0.95) |
| Computer Self-Efficacy (CSE) | 5.41 (0.87) | 5.58 (0.88) | 5.55 (0.96) | 5.53 (0.86) |

male and female students in the face-to-face group have a comparable mean for each dependent variable. In contrast, we note greater differences in mean values between male and female students supported by technology-mediated learning. We cannot attribute these differences to computer self-efficacy, which has been identified as an important factor for explaining the relatively low learning performance by female students in technology-mediated learning (Chen, 1986), because our subjects, both male and female, report comparable computer self-efficacy. Overall, our data support H1, H3, and H4; but not H2.

According to our results, male students seem more motivated in technology-mediated learning than female students. This finding may be explained in part by the general between-gender difference in intrinsic motivation that involves technology. As Li (2006) notes, male students tend to enjoy using computer technology more than their female counterparts; e.g., enjoyment or satisfaction derived from trying out new software or using it for different purposes. Nevertheless, female students in our sample perceive their learning in a technology-mediated setting more effective and satisfactory. These between-genders differences observed in the outcomes of technology-mediated learning are intriguing and deserve further investigation in future research.

### *Study 2 – Technology-Mediated Learning and Learning Style*

Our subjects were freshmen at a major university in Hong Kong who enrolled in the freshman English class mandated by the university. A total of 507 students took part in the study, accounting for 29.4% of the targeted population. Incomplete responses were removed; as a result, our effective sample size is 438. Both technology-mediated and face-to-face groups were highly comparable in age, advanced-level English examination scores, general computer competency, and Internet experiences and usage, as shown in Table 4. Notably, we had a larger proportion of males (69% versus 44%) and abstract thinkers (63% versus 53%) in the technology-mediated group than in the face-to-face group.

*Table 4. Summary of demographics in English learning study*

| | *Face-to-face group* | *Technology-mediated group* |
|---|---|---|
| Age | 19.0 | 19.2 |
| Gender | Male: 107 (44.0%)<br>Female: 136 (56.0%) | Male: 135 (69.2%)<br>Female: 60 (30.8%) |
| Affiliated School | Business: 121 (49.8%)<br>Engineering: 46 (18.9%)<br>Science: 76 (31.3%) | Business: 45 (23.1%)<br>Engineering: 99 (50.8%)<br>Science: 51 (26.2%) |
| A-Level English Exam | A = 6; B = 22; C = 54; D = 79;<br>E = 39; F = 4 | A = 1; B = 11; C = 28; D = 65;<br>E = 73; F = 0 |
| Learning Style | Abstract conceptualization: 153 (63%)<br>Concrete experience: 90 (37%)<br>Active experimentation: 150 (62%)<br>Reflective observation: 93 (38%) | Abstract conceptualization: 103 (53%)<br>Concrete experience: 92 (47%)<br>Active experimentation: 140 (72%)<br>Reflective observation: 55 (28%) |
| Computer Skills | 4.26 (on a 7-point scale) | 4.71 (on a 7-point scale) |
| Average Internet Usage Per Week | < 5 hours: 39 (16%)<br>5–10 hours: 59 (24%)<br>11–15 hours: 59 (24%)<br>16–20 hours: 33 (14%)<br>> 20 hours: 53 (22%) | < 5 hours: 25 (13%)<br>5–10 hours: 40 (21%)<br>11–15 hours: 29 (15%)<br>16–20 hours: 25 (13%)<br>> 20 hours: 76 (39%) |

The Cronbach's alpha values are satisfactory: 0.79 for perceived learning effectiveness, 0.78 for learnability, 0.65 for learning community support, and 0.90 for learning satisfaction; all exceed the common threshold of 0.6 for an exploratory study (Nunnally, 1978). We examined the convergent and discriminant validity by performing an exploratory factor analysis. As shown in Table 5, items measuring the same construct exhibit substantially higher loadings than do those measuring other constructs. The eigenvalue of each extracted factor exceeds 1.0, a common threshold used by previous research (Kim & Mueller, 1978). Overall, our instruments exhibit adequate reliability and convergent/discriminant validity.

We performed a GLM analysis on each dependent variable. As summarized in Table 6A, we observe a significant effect of technology-mediated learning on perceived learning effectiveness and learning community support. We also note that technology-mediated learning has a significant interaction effect with learning style on perceived learnability. Overall, our experimental results suggest the important role of learning style for explaining the outcomes associated with technology-mediated learning.

Further analyses show students' information perceiving and acquisition moderates their learning outcomes in technology-mediated learning. As shown in Table 6B, students' information perceiving/acquisition preferences significantly affect their perception of learnability. Specifically, concrete thinkers seem to find the course more difficult to learn compared with abstract thinkers, in support of our H7. The technology-mediated learning system used in the study resembles most existing systems; as a consequence, concrete thinkers may be put in a relatively disadvantaged position, compared with abstract thinkers. This suggests future technology-mediated learning system designs need to consider offering more concrete experiences to target students; e.g., through effective use of multimedia and interactive contents.

*Table 5. Analysis of convergent and discriminant validity for latent constructs in English learning study*

| *Question items* | *Components extracted* | | | |
|---|---|---|---|---|
| | *Factor 1* | *Factor 2* | *Factor 3* | *Factor 4* |
| Learning Satisfaction (LS-1) | **0.72** | 0.32 | 0.15 | 0.16 |
| Learning Satisfaction (LS-2) | **0.73** | 0.31 | 0.06 | 0.18 |
| Learning Satisfaction (LS-3) | **0.67** | 0.14 | 0.21 | 0.13 |
| Learning Satisfaction (LS-4) | **0.68** | 0.38 | 0.20 | 0.23 |
| Learning Satisfaction (LS-5) | **0.55** | 0.46 | 0.13 | 0.31 |
| Learning Satisfaction (LS-6) | **0.65** | 0.18 | 0.43 | 0.23 |
| Learning Satisfaction (LS-7) | **0.68** | 0.26 | 0.28 | 0.25 |
| Perceived Learning Effectiveness (PLE-1) | 0.19 | **0.67** | 0.15 | 0.21 |
| Perceived Learning Effectiveness (PLE-2) | 0.16 | **0.80** | 0.06 | 0.00 |
| Perceived Learning Effectiveness (PLE-3) | 0.20 | **0.74** | 0.17 | 0.06 |
| Perceived Learning Effectiveness (PLE-4) | 0.22 | **0.69** | 0.07 | 0.13 |
| Perceived Learning Effectiveness (PLE-5) | 0.45 | **0.52** | 0.11 | 0.11 |
| Perceived Learning Effectiveness (PLE-6) | 0.35 | **0.54** | 0.17 | 0.05 |
| Perceived Course Learnability (PCL-1) | 0.09 | 0.10 | **0.73** | 0.08 |
| Perceived Course Learnability (PCL-2) | 0.06 | 0.08 | **0.77** | 0.15 |
| Perceived Course Learnability (PCL-3) | 0.46 | 0.16 | **0.62** | -0.02 |
| Perceived Course Learnability (PCL-4) | 0.37 | 0.11 | **0.70** | 0.01 |
| Perceived Course Learnability (PCL-5) | 0.22 | 0.27 | **0.50** | 0.37 |
| Perceived Learning Community Support (PLCS-1) | 0.09 | 0.20 | 0.40 | **0.60** |
| Perceived Learning Community Support (PLCS-2) | 0.30 | 0.13 | 0.00 | **0.72** |
| Perceived Learning Community Support (PLCS-3) | 0.20 | 0.04 | 0.09 | **0.77** |
| Eigenvalue | 8.48 | 1.82 | 1.33 | 1.06 |
| Percentage of variance explained | 19.87 | 16.89 | 13.80 | 9.86 |

*Table 6A. GLM analysis results*

| *Dependent variables* | *Sig.* | | |
|---|---|---|---|
| | *Learning style* | *Tech-mediated learning* | *Learning Style × Tech-mediated learning* |
| Objective Learning Effectiveness (OLE) | 0.132 | 0.749 | 0.897 |
| Perceived Learning Effectiveness (PLE) | 0.351 | 0.015* | 0.459 |
| Perceived Course Learnability (PCL) | 0.392 | 0.210 | 0.044* |
| Perceived Learning Community Support (PLCS) | 0.388 | 0.012* | 0.175 |
| Learning Satisfaction (LS) | 0.640 | 0.727 | 0.586 |

* Significant at 0.05 level.

*Table 6B. A comparison of descriptive statistics*

| *Dependent variables* | *Mean (S.D.)* | | *p-value* |
|---|---|---|---|
| | *Abstract thinkers* | *Concrete thinkers* | |
| Objective Learning Effectiveness (OLE) | 2.80 (7.89) | 1.97 (7.26) | 0.45 |
| Perceived Learning Effectiveness (PLE) | 4.52 (0.86) | 4.56 (0.74) | 0.69 |
| Perceived Course Learnability (PCL) | 4.64 (0.77) | 4.39 (0.81) | 0.03* |
| Perceived Learning Community Support (PLCS) | 3.90 (0.96) | 3.98 (0.87) | 0.54 |
| Learning Satisfaction (LS) | 4.35 (1.05) | 4.22 (0.89) | 0.38 |

* Significant at 0.05 level.

We summarize our hypothesis testing results in Table 7, As shown, our data support H7 but do not support H5, H6, H8, or H9.

*Table 7. Summary of hypothesis testing results*

| *Hypotheses* | *Results* |
|---|---|
| H1: There exists a significant between-gender difference in the perceived learning effectiveness among students supported by technology-mediated learning versus by classroom-based face-to-face learning. | Supported |
| H2: There exists a significant between-gender difference in the perceived learnability among students supported by technology-mediated learning versus by classroom-based face-to-face learning. | Not Supported |
| H3: There exists a significant between-gender difference in the learning motivation among students supported by technology-mediated learning versus by classroom-based face-to-face learning. | Supported |
| H4: There exists a significant between-gender difference in the learning satisfaction among students supported by technology-mediated learning versus by classroom-based face-to-face learning. | Supported |
| H5: In technology-mediated learning, students who are abstract thinkers exhibit higher objective learning effectiveness than do those who are concrete thinkers. | Not Supported |
| H6: In technology-mediated learning, students who are abstract thinkers perceive greater learning effectiveness than do those who are concrete thinkers. | Not Supported |
| H7: In technology-mediated learning, students who are abstract thinkers perceive the overall course more learnable than do those who are concrete thinkers. | Supported |
| H8: In technology-mediated learning, students who are abstract thinkers consider the learning community support to be stronger than do those who are concrete thinkers. | Not Supported |
| H9: In technology-mediated learning, students who are abstract thinkers show higher learning satisfaction than do those who are concrete thinkers. | Not Supported |

## DISCUSSION

The main objective of this study is to explore the equality implications of technology-mediated learning, while ruling out potential confounding effects that arise from "one-shot" designs and unreliable measurements. In both the Photoshop and English learning studies, we include multiple learning outcome measures, use statistically validated measurement scales, and include classroom-based, face-to-face learning as a control. Our measurements and study designs allow us to generate empirical results regarding the influences of gender and learning style on students' learning outcomes in technology-mediated learning, critical to digital inclusion and equality in education. Our results show the learning outcomes associated with technology-mediated learning to be affected by individual differences (e.g., gender, learning style). Equipped with this understanding, system developers and educators should be cautious about unexpectedly putting some students in a disadvantaged position when pursuing the benefits of technology-mediated learning, and addressing such undesirable influences appropriately from the perspective of system design, teaching pedagogy, or both.

We made several important observations from our studies. First, concrete thinkers may find the materials delivered through technology-mediated learning more difficult to learn than abstract thinkers. Second, female students may be less motivated in a technology-mediated learning environment than male students. Third, male students may perceive technology-mediated learning less effective and less satisfactory, compared with female students. To foster equally effective learning environments, system developers and educators should examine and reduce partiality in any key aspect of students' learning experiences. For example, to avoid placing concrete thinkers in a disadvantaged position, a technology-mediated learning system should incorporate effective multimedia presentations to create the realism and interactivity simulating "live" learning situations; e.g., network simulation software Packet Tracer by Cisco. Adaptive systems can also be used to accommodate the needs of individual students with different learning styles (Triantafillou, Pomportsis, Demetriadis, & Georgiadou, 2002). To minimize gender inequity, instructors in a technology-mediated learning setting can provide students with sufficient incentives for completing learning exercises, together with effective assessments. Furthermore, we can enhance students' learning outcomes (e.g., effectiveness, satisfaction) in technology-mediated learning by providing increased interactivity, functionality, instruction, and administration (Shen, Hiltz, & Bieber, 2006). Perceived support also provides an important influence on students' learning satisfaction in technology-mediated learning (Wang, 2003). Instructors should take advantage of online chat and discussion forums to foster a supportive learning environment that encourages exchanges and knowledge sharing among students through these channels.

## CONCLUSION

We contribute to technology-mediated learning research in several ways. First, we explore the equality of students' learning outcomes in technology-mediated learning and produce empirical evidence suggesting the importance of individual differences in affecting the equality; e.g., gender and learning style. Specifically, we empirically reinforce, with methodological rigor, the theory that technology-mediated learning itself does influence students differently, suggesting potential undesirable inequality of students' learning outcomes in technology-mediated learning settings. Second, we consider the effectiveness of technology-mediated learning as multifaceted and observe that students may benefit from technology-mediated learning in some aspects of learning but be placed in a disadvantaged position in other aspects. Thus, it is important to use multiple measures to examine learning outcomes. By doing so, we can obtain a comprehensive understanding of the learning equality in technology-mediated learning. Third, our results suggest that the subject (topic) of learning may play a role in the equality of technology-mediated learning. When the subject is computer-related, female learners may be less motivated to engage in additional (optional) learning activities; when the learning of a subject requires concrete experimentation, concrete thinkers may find learning more difficult.

Our findings highlight the need to consider individual differences when designing technology-mediated learning systems as well as various courses to be delivered through technology-mediated learning partially or completely. We explore practical implications of our findings and identify several ways by which instructors can avoid introducing unfairness in technology-mediated learning unintentionally. For example, games and simulations of a real-world phenomenon can be used as an effective substitute of concrete experience for concrete thinkers. Proper assessments can be used to motivate students, particularly female students, to participate in online activities in science or technology related subjects. Improved interactivity, functionality, instruction, administration and learning support can help to assure students' perceived learning effectiveness and satisfaction at a desirable level.

Our research has several limitations that should be considered when applying our findings to other technology-mediated learning settings. First, our subjects are undergraduate students in Hong Kong; there might be some cultural differences with respect to the influences of individual differences in technology-mediated learning. Thus, our findings may not be totally applicable to students in a different culture. Second, our results are derived from examinations of two specific subjects; i.e., language and Web content publishing. In our Photoshop experiment, female subjects seem less motivated in technology-mediated learning, as compared with male subjects. This finding is not consistent with the findings of McSporran & Young (2001), who show that female students tend to be more motivated than their male counterparts in a computer-programming course delivered through technology-mediated learning. Therefore, it is important to be mindful about the variables that do not show significant influences on the equality of students' learning outcomes in our studies, but may exhibit important effects in other subjects or student groups.

In turn, these limitations point to several future research directions worthy of our investigative attention. First, we need to examine the relative importance of key individual differences in various cultures. Second, to make the results more generalizable, we need to expand our evaluations by including different student groups and subjects. Third, it is important to develop quantitative measures for assessing the "fit" between technology-mediated learning and a subject or a learning task. This allows us to make informed decisions regarding whether a course or a learning task is likely to be effectively and efficiently delivered through technology-mediated learning. Fourth, we must consider other essential learning outcome measures. Although more comprehensive than many prior studies examining technology-mediated learning, the dependent variables included in our studies can be extrapolated. The use of additional key learning outcome measures enable a fuller depiction of the underlying inequality concerns in technology-mediated learning and encourage the consideration of different and perhaps complementary research methods or designs. Learning is a complex activity; the effectiveness or outcomes of technology-mediated learning may be affected by a host of independent or interrelated factors. Such factors can pertain to the learning system or individual characteristics, which together can create significant interaction effects. Continued efforts are needed to further examine how these factors may affect the equality in students' learning outcomes and experiences in technology-mediated learning. By doing so, we can identify key problems hindering equality and explore how to address them, from a system design or pedagogical perspective, to ensure that students can benefit equally from technology-mediated learning.

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## APPENDIX

*A. Question Items for Photoshop Study*

Learning Satisfaction (LS)

LS-1: I like the idea of learning Photoshop in a lab like this.
LS-2: Learning Photoshop by attending a lab like this is a great idea.
LS-3: My learning experience in this lab is positive.
LS-4: My learning of Photoshop in this lab is pleasant.

Perceived Learning Effectiveness (PLE)

PLE-1: In this lab, I have the opportunities to practice what I learn about Photoshop.
PLE-2: The pace at which the materials are presented in the lab is appropriate for my learning.
PLE-3: Overall, I have good control over the presentation of the materials covered in this lab.

Perceived Learnability (PL)

PL-1: The lab materials are delivered in a way that is easy to for me to comprehend.
PL-2: The lab contents are presented in a way that is clear for me to understand.
PL-3: Learning Photoshop in a lab like this is enjoyable.

Computer Self-Efficacy (CSE)

In general, I can use computer technology to complete a task ...
CSE-1: if I have seen someone else using it before trying it myself.
CSE-2: if I can call someone for help if I got stuck.
CSE-3: if someone else can help me getting started.
CSE-4: if someone shows me how to do it first.

*B. Question items used in English Learning Study*

Learning Satisfaction (LS)

LS-1: I like the idea of learning English in a class like this; i.e., the one I have this semester.
LS-2: Learning by taking a course like this is a good idea.
LS-3: My learning experience in this course is positive.
LS-4: Overall, I am satisfied with the course.
LS-5: In sum, my learning in the course is pleasant.
LS-6: Learning English in a class like this is enjoyable.
LS-7: As a whole, the course is effective for my learning.

Perceived Learning Effectiveness (PLE)

PLE-1: This course supports my learning English by providing many resources and tools.
PLE-2: This course allows me to learn English in many different ways.
PLE-3: The course gives me chances to review what I learn.
PLE-4: This course allows me to improve my understanding of the basic elements of English.
PLE-5: This course allows me to learn to identify the central issues in learning English.
PLE-6: This course allows me to learn factual aspects of using English.

Perceived Course Learnability (PCL)

CL-1: I have no difficulty understanding course materials delivered in class (or via the Web).

CL-2: Overall, I find this course easy to learn.

CL-3: The course is delivered in a way that is easy to learn.

CL-4: The course content is presented in a way that is easy to understand.

CL-5: I find the delivery of the course content clear; i.e., not ambiguous.

Perceived Learning Community Support (PLCS)

PLCS-1: The course makes it easy for me to learn from other students.

PLCS-2: The course facilitates my sharing of what I have learned with other students.

PLCS-3: It is easy for me to discuss with other students concerns related to course contents.