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A Meta-Analysis of the Effect of IT on Learning Outcomes

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ABSTRACT

This study provides an updated meta-analysis on the effects of using Information Technology (IT) in education. Fifty-eight experimental studies conducted on the application of IT in the classrooms were integrated and analyzed. Positive effect sizes were found for learning outcomes including academic achievement, knowledge retention, task performance, self-reported learning and self-efficacy. Further analysis revealed the main effects to be significantly moderated by several factors, categorized under learner and course characteristics.

1. INTRODUCTION

Emerging as a precious asset in education, technology is viewed as a potential element that can influence traditional pedagogy. Learning effectiveness has been a major issue in recent research, and the growing knowledge repository has implications on all levels of education with the advent of new technologies. The goals of using Information Technology (IT) in education are to enhance teaching and learning, and to increase the efficiency and effectiveness of the educational organization (Windschitl, 1998). This is readily reflected in the large amount of resources invested in IT spending (Volery and Lord, 2000). Concomitantly, calls for greater depth and breadth in the studies for technology-mediated learning (Alavi and Leidner, 2001; Owston, 1997) indicate growing interest in the pedagogical impacts of IT on education.

IT is increasingly used to complement or replace conventional teaching methods (Leidner and Jarvenpaa, 1995). Many researchers believe that the use of IT is inherently 'good' for learning (Niemiec et al., 1996). Yet, the application of old solutions to new problems in online learning usually leads to the 'no significant difference' phenomenon (Russell, 2002). There is a need to understand the strengths and weaknesses, as well as the appropriateness of implementing IT in schools. Conflicts in research findings (Kulik and Kulik, 1991; Niemiec et al., 1996) show the conditions where IT is beneficial have ramifications not completely understood despite the plethora of research commentaries. To reach general conclusions, reviewers must consider results from studies in varied settings and under different conditions. A rigorous approach involves meta-analysis, defined as a set of statistical procedures for accumulating experimental results across independent studies that address a related set of research questions (Hunter and Schmidt, 1990).

The current study used a meta-analytic approach to integrate the inconsistent results on the use of IT in education. The focus here is on the use of technological tools for instructional purposes, although management functions may be aided to increase educational productivity. Two important research questions this study aims to address are: *What are the effects of the use of IT on commonly researched educational outcomes? Under which conditions does the use of IT appear to be most effective?* The second question differentiates the current study from the earlier meta-analyses (Kulik and Kulik, 1991), which focused principally on the main effects (i.e., whether or not IT can help to learn or teach). As importantly, the current study analyzes the most up-to-date sample (1990-2002).

2. DEPENDENT VARIABLES: LEARNING OUTCOMES

2.1 Actual Learning

Cognitive and affective dimensions are important insofar as learners are concerned (Kraiger et al., 1993). The cognitive dimension is represented by academic achievement, knowledge retention, and task performance. *Academic achievement* is broadly defined as any increase in learning, usually measured on a final examination. *Knowledge retention* refers to the performance on a follow-up examination, usually the same examination as the first one, given some time after the completion of the instruction program (Dees, 1991). *Task performance* is another measure that is believed to represent the amount of learning (Leidner and Jarvanpaa, 1995).

2.2 Perceived Learning

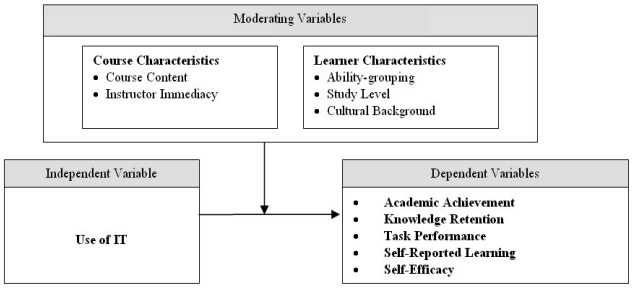
Experimental evidence obtained from past studies indicated that instruction using technological tools was efficacious in terms of perceived learning defined by self-reported learning and self-efficacy. *Self-reported learning* is associated with learners' perceptions of their learning process (Alavi and Leidner, 2001). *Self-efficacy* refers to the degree to which the learners feel capable of learning from a given method (Leidner and Jarvanpaa, 1995).

How IT influences the learning outcomes depends on the context. Review of the literature highlights characteristics of the learner and course as potential moderators. Figure 1 depicts the moderating relationships. The next section deliberates on the potential moderators and the conditions each assumes.

3. POTENTIAL MODERATING EFFECTS

From the existing literature, two important categories of moderators pertain to course characteristics and learner characteristics. In this paper we identify two course characteristics (course content and in-

Figure 1. Research Model



structor immediacy) and three learner characteristics (ability-grouping, study level, and cultural background) as potential moderating variables.

Course content can be differentiated into hard and soft disciplines (Biglan, 1973). Examples of hard disciplines include physics, biology, engineering, and medicine. Examples of soft disciplines include social sciences, humanities, and languages. We observed that hard disciplines have been the preferred subject matter in most research experiments. It is possible that learners benefit more from IT in hard disciplines by invoking feedback and individualized-pacing features (Dees, 1991). The effect of computer-based instruction on learning was rather low for soft disciplines (Niemiec et al., 1996). General conclusions, that hard disciplines have a greater moderating effect on learning, have been made (Niemiec et al., 1996). This expectation is indicated in Table 1.

Instructor immediacy is differentiated into high vs. low. It is considered low when the course is to be "taught" using IT totally (where IT becomes a substitute for instructor), and high when partially (where IT supplements the instructor). Computer-assisted instruction, for example, is generally considered a form of substitute for instructors, whereas networked learning is supplementary as instructor presence is still distinctive. Substitution usually refers to situations where computers are tutors that direct the activities of the learner toward knowledge acquisition. Supplementation, on the other hand, usually means that computers are used as cognitive tools to help learners construct their knowledge.

Ability-grouping refers to the combination of learners with different capacity to comprehend learning concepts and control learning. The two conditions assumed are homogeneous and heterogeneous. In a heterogeneous group, the high-ability learners may act as motivational models to help their low-ability counterparts in the learning process. Within-class ability groupings are found to produce positive academic impacts (Kulik and Kulik, 1991).

Study level is examined in terms of "school" or "college". Most studies reasonably assumed that school or pre-college learners (grades one to twelve) are younger than the college or university learners. Relatively speaking, younger learners are able to adapt to a variety of uses of IT more easily, and are less resistant to accept the use of IT in the course curriculum (Kulik and Kulik, 1991). To add to these contrasts is the premise that technology is not as effective in teaching more subtle ideas and concepts (Windschitl, 1998). Further, school children may need a higher level of guidance from and interaction with instructors, as compared to college learners who are expected to learn more independently, with instructors acting as facilitators rather than instructors (Owston, 1997). Insofar as promoting interaction, IT should play a greater role in schools than in colleges.

Cultural background assumes two conditions, Western and Eastern. Culture is viewed broadly here as the beliefs, philosophy, values, perceptions, and patterns of action by individuals and groups (Chen et al., 1999). While differences between the Western and Eastern cultures form a major topic of study in and of itself, for the purposes here it suffices to highlight the following. Sleeter and Grant (1993) have discussed differential cultural perspectives indicating a general tendency of Western culture to value individualism, independence, and functionally-based human interactions. In contrast, people with non-Western culture orientations are portrayed as emphasizing group cooperation and affective expression. Self-reported learning and self-efficacy are expected to be more congruent to learners in the western culture.

Table 1. Potential Moderating Relationships

Primary Causal Relationship	Potential Moderating Variables and Effects on Primary Relationship	
Use of IT and Academic Achievement	Course Content	Hard > Soft*
	Instructor Immediacy	High > Low
	Ability-grouping	Heterogeneous > Homogeneous
	Study Level	School > College
Use of IT and Knowledge Retention	Course Content	Hard > Soft
	Instructor Immediacy	High > Low
	Ability-grouping	Heterogeneous > Homogeneous
	Study Level	School > College
Use of IT and Task Performance	Course Content	Hard > Soft
	Instructor Immediacy	High > Low
	Ability-grouping	Heterogeneous > Homogeneous
	Study Level	School > College
Use of IT and Self-Reported Learning	Course Content	Hard > Soft
	Instructor Immediacy	High > Low
	Cultural Background	Western > Eastern
Use of IT and Self-Efficacy	Course Content	Hard > Soft
	Instructor Immediacy	High > Low
	Cultural Background	Western > Eastern

**This should be read as "The relationship between use of IT and academic achievement is stronger (or more evident) in hard disciplines than in soft disciplines".*

4. SUMMARY OF META-ANALYSIS

1.1 Data Sources

The search for related articles took four months, followed by regular monthly updates for the next three months. The primary studies located for this meta-analysis came from several sources. A computerized search of online databases resulted over a hundred studies that used the words such as *technology, computer, communication, distance learning, Internet, academic achievement, skills, retention, school,* and *college* in their titles or abstracts. Additional studies were identified when study levels, e.g., *fifth grade*, were used. A total of two hundred and twenty-four studies with abstracts were generated in the computer search. Only one hundred and fifteen studies from online journals were in full text with available information for further analysis.

Physical journals containing research related to technology in education were also identified, and these sources were reviewed from 1990 to the most recent issue available to check for additional references. Secondary sources for searching the studies were bibliographies from documents located through computer searches and journal articles. Finally, dissertation abstracts were searched for any doctoral thesis not found in the previous efforts. Among other criteria for inclusion in this meta-analysis, a study had to include quantitative results in which educational outcome variables were the dependent variables for both experimental and control groups, and content of the course had to be part of regular curriculum in the implementation of IT. Fifty-eight sets of results met the inclusion criteria[1]. Those that failed to meet the criteria either did not statistically analyze the data, or reported inadequate statistics (needed for calculations).

1.2 Variables Coded from Studies

To describe the main features of the studies, the following variables were coded from each study: three variables that define learner characteristics include ability-grouping, study level, and cultural background; two variables defining course characteristics include course content and instructor immediacy. A reliability check was conducted on these variables coded. A research assistant helped to code the study characteristics. The rate of agreement on the coding was 96%.

4.3 Data Analysis

We adopted the meta-analytic approach (Hunter and Schmidt, 1990) which involved (1) coding the studies for prominent features, (2) creating a common scale for each outcome, and (3) using statistical methods combining the results into a quantified conclusion. To quantify IT effects, each outcome was coded on a common scale of effect size, which measures the strength of a relationship between the treatment and outcome. Table 2 shows the results of our analysis. There is an overall effect when the mean effect size differs significantly from zero. All main effects were significant and positive. Homogeneity statistic showed that the effect sizes were heterogeneous for all dependent variables. Moderating variables were used to account for the variation in technol-

ogy and no-technology differences. The regression model was used to test the effect of the moderating variables. The categorical variables (course content, instructor immediacy, ability-grouping, study level, and cultural background) were coded as dummy variables. In general, the R^2 values indicated that the predictors could explain the variability of the effect sizes. The small values of Q_E (error sum of squares) compared to the critical value also showed a good fit of each model.

5. DISCUSSION

1.1 Course Characteristics and IT

Course content was found to moderate the impact of IT on actual learning outcomes. Academic achievement of learners was higher when IT was used to teach hard disciplines. A plausible explanation is that the structure of hard disciplines is commensurate with the discrete and objective steps that are inherent in technological instruction (Stillman et al, 1999). For example, in Mathematics specifically, drill-and-practice software can help young learners develop competence in counting and sorting (Swan, 1991). On the contrary, a soft subject such as English language involves a more holistic approach that may be incongruent with the use of IT (Davidson et al., 1996). As predicted, the effect on knowledge retention for hard disciplines was higher than that for soft subjects.

Instructor immediacy provides various types of advisement to assist learners in making informed decisions. The instructor can help temper comments on learners' individual characteristics, especially in settings devoid of psycho-social cues available in a traditional classroom (Kitchen and McGougall, 1999). One point to note is that although IT produced modest effects in a typical study, some studies in education, psychology, and music education reported unusually large effects. Researchers may want to scrutinize results of these atypical studies to point the way for better uses of IT.

Table 2. Results of Analysis

Dependent Variable	N	Mean–Weighted ES[a] ($\bar{d}$)	Homogeneity Statistic (Q_T)[b]	Moderating Variable	Regression Coefficient	R^2	Q_E	Fail-Safe N, N_{fs}
Academic Achievement	52	.507**	1688.86**			.724	22.42	98
				Course Content[i]	.458**			
				Instructor Immediacy[ii]	.114			
				Ability-Grouping[iii]	.542**			
				Study Level[iv]	.061			
Knowledge Retention	36	.912**	520.67**			.732	24.31	99
				Course Content	.295*			
				Instructor Immediacy	.045			
				Ability-Grouping	-.552**			
				Study Level	-.254			
Task Performance	32	.879**	1354.78**			.717	21.35	78
				Course Content	-.021			
				Instructor Immediacy	.016			
				Ability-Grouping	.032			
				Study Level	.539**			
Self-Reported Learning	32	.595**	332.01**			.731	24.04	87
				Course Content	-.109			
				Instructor Immediacy	.474**			
				Cultural Background[v]	.499**			
Self-Efficacy	28	.892**	1249.81**			.698	20.10	73
				Course Content	.304*			
				Instructor Immediacy	-.010			
				Cultural Background	.501**			

*NOTE: N = number of studies; * p < .05; ** p < .01*

[a] Effect size (ES) refers to the strength of a relationship between the use of IT and the dependent variable. It measures the difference of outcomes between the use of IT and the non-use of IT in education. It is positive for differences in the use of IT direction and negative for differences in the non-use of IT direction. Each model is weighted least square regression with weights calculated as the reciprocal of the variance for each effect size.

[b] Significance indicates rejection of the hypothesis of homogeneity.

i. 0: Soft; 1: Hard;
ii. 0: Low (Substitute); 1: High (Supplement);
iii. 0: Homogeneous; 1: Heterogeneous;
iv. 0: College; 1: School;
v. 0: Eastern; 1: Western

1.2 Learner Characteristics and IT

Ability-grouping was found to moderate IT's effect on academic achievement and knowledge retention. Heterogeneous groups are found to perform better academically. IT must be credited, even if indirectly, for its role in increasing interest and motivation. The results also suggest that IT may reduce the differences in learning achievement among learners with different cognitive abilities.

On the other hand, the analysis indicated surprisingly that the homogeneously-grouped learners had the tendency to do better in a retest two to eight weeks later. Learners in groups with heterogeneous ability levels had done well in the first examination, but did not perform in the retention tests. It is plausible that the lower ability learners, with the experience of the first test, and given a longer time to assimilate what they learned, would outperform the higher ability learners after a few weeks. Achievement and retention were also found to be correlated (coefficient = -.88; $p<.01$). Generally, learners who initially performed better deteriorated in their performance for the retention test.

Study level showed moderating effects on task performance. The impact of IT in fostering learning was more pronounced among school learners. Manifested experience of the learners may influence the ability of IT to effectively communicate information. Learners may be more flexible in adapting to IT for complex tasks at young ages. With increasing age, these learners may become less susceptible to forces (IT applications) that would serve to aid them in carrying out their tasks.

The cultural background of the learners was found to significantly moderate the effects of the use of IT on self-reported learning and self-efficacy. Learners in the western countries were found to perceive learning to be better when IT was used to teach the course. However, the literature showed that there were exceptional cases. For example, the highly meritocratic and technologically-biased system of Singapore might produce learners who perceived learning to be satisfactory (Ho, 1995). The findings also suggest that caution has to be taken when IT is being implemented in an eastern culture.

6. CONCLUDING REMARKS

While technology can make a difference, learning ultimately depends on the learner, the course characteristics, the instructional design, and the myriad of variables that interact as a function of effectiveness. Technological instruction that optimizes the combination of effective variables will probably be the most effective. This induces several research and practical implications.

This study focused on a comparison between the outcome effects of the use of IT and traditional methods of instruction. One important point to note is that there is no singularly and overridingly influential moderating variable on most of the dependent variables. The absence of a strong moderating factor indicates the importance of examining various factors and how their specific features interact to influence the pedagogical processes. After overly exclusive and probably inevitable focus on technical development, educational technologists should attach increasing importance to the contributions of inherent learner and course characteristics in their research agenda.

On the practical aspect, in order to maximize the potential of technology, it is necessary for educators to match the use of IT with the educational goals. Designers of IT applications need to identify the optimum combinations of attributes and treatments incorporated into their IT design. New curricula for teaching will have to be developed in light of the new horizons opened up by the information technologies. While most studies have treated the use of IT as a black box with its products defined on pedagogical outcomes such as examination scores, future work should analyze the processes involving IT usage. Only then will the understanding of advantages and disadvantages help educators in deciding what and how to use IT applications that are more suitable in the unique milieu of the educational environment.

[1]The list of primary studies included in the meta-analysis is available from the authors upon request.

REFERENCES

Alavi, M. and Leidner, D. E. (2001). Research Commentary: Technology-Mediated Learning – A Call for Greater Depth and Breadth of Research. *Information Systems Research, 12(1),* 1-10.

Biglan, A. (1973). Relationships Between Subject Matter Characteristics and the Structure and Output of University Departments. *Journal of Applied Psychology, 57(3),* 204-213.

Chen, A. Y., Mashhadi, A., Ang, D. and Harkrider, N. (1999). Cultural Issues in the Design of Technology-Enhanced Learning Systems. *British Journal of Educational Technology, 30(3),* 217-230.

Davidson, J., Elcock, J. and Noyes, P. (1996). A Preliminary Study of the Effect of Computer-Assisted Practice on Reading Attainment. *Journal of Research in Reading*, 19(2), 102-110.

Dees, R. L. (1991). The Role of Cooperative Learning in Increasing Problem-Solving Ability in a College Remedial Course. *Journal for Research in Mathematics Education, 22(5),* 409-421.

Ho, M. S. (1995). *Learning and Teaching in Cyberspace: an Empirical Investigation of Computer-Assisted Instruction for Geography*. Academic Exercise. Dept. of Geography, National University of Singapore.

Hunter, J. E. and Schmidt, F. L. (1990). *Methods of Meta-Analysis.* Newbury Park, CA: Sage.

Kraiger, K., Ford, J. K. and Salas, E. (1993). Application of Cognitive, Skill-Based, and Effective Theories of Learning Outcomes to New Methods of Training Evaluation. *Journal of Applied Psychology, 78(2),* 311-328.

Kulik, C. C. and Kulik, J. (1991). Effectiveness of Computer-based Instruction: An Updated Analysis. *Computers in Human Behavior, 7(12),* 75-94.

Leidner, D. E. and Jarvanpaa, S. L. (1995). The Use of Information Technology to Enhance Management School Education: A Theoretical View. *MIS Quarterly*, 19, 265-291.

Niemiec, R. P., Sikorski, C. and Walberg, H. J. (1996). Learner-Control Effects: A Review of Reviews and a Meta-Analysis. *Journal of Educational Computing Research, 15(2),* 157-174.

Owston, R. D. (1997). The World Wide Web: A Technology to Enhance Teaching and Learning? *Educational Researcher, 26(2),* 27-33.

Russell, T. L. (2002). The "No Significant Difference" Phenomenon. Online: *http://teleeducation.nb.ca/*nosignificantdifference/

Sleeter, C. and Grant, C. (1993). *Making Choices for Multicultural Education.* New York: Macmillian Publishing Co.

Stillman, G., Alison, J. and Croker, F. (1999). Using the WWW to Improve Medication Calculation Skills. *Innovations in Education and Training International, 36(1),* 17-25.

Swan, K. (1991). Programming Objects to Think With: Logo and the Teaching and Learning of Problem Solving. *Journal of Educational Computing Research*, 7(1), 89-112.

Volery, T. and Lord, D. (2000). Critical Success Factors in Online Education. *The International Journal of Educational Management, 14(5),* 216-223.

Windschitl, M. (1998). The WWW and Classroom Research: What Path Should We Take? *Educational Researcher, 27,* 28-33.