# TECHNOLOGY TOOLS AND SUCCESS IN STATISTICS: INTERPRETING THE RESEARCH

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*The purpose of the present research study was to examine the effectiveness of using various technology tools to enhance statistics instruction using meta-analytic techniques. A total of 148 effect sizes were obtained from 62 individual articles. A mean study-weighted effect size of 0.280 was found across all studies and this value was statistically significant, t (62.991) = 4.467, p < 0.001. However, considerable variance in effect sizes remained unexplained suggesting that the mean study-weighted effect size found when considering all studies was moderated by one or more study characteristics. Further analyses examined differences in effect sizes across online vs. face-to-face courses, function of technology use (supplemented or substituted instruction), duration of instruction, instructor bias (same vs. different instructions), research design, and publication status (published vs unpublished studies). Only the difference in effect sizes between online and face-to-face courses was statistically significant. Implications for using various technology tools are discussed.*

## INTRODUCTION

Instructors of statistics courses have been among the earliest and most common to incorporate technology for the purpose of enhancing instruction. In 1987, Rogers commented that, among psychology courses, computers were most often used in statistics courses, permitting students to spend less time doing calculations and allowing for more time for conceptual understanding. As early as 1991, a survey indicated that 70% of introductory statistics courses used computer software (Khamis, 1991). Just over 10 years ago Fernandez and Liu (1999) commented that the questions still remained regarding what and how specific software should be integrated into the teaching and learning process. Although recent studies delve into these questions (see, for example, Schenker, 2007 and Givens, 2005) these questions persist today and this study seeks to provide contemporary clarity to these questions.

The purpose of the present research study was to examine the effectiveness of using technology to enhance statistics instruction using meta-analytic techniques. This study also compared the effects of several additional program/intervention and methodological/study characteristics based on the availability of studies that exhibit such characteristics.

## METHODS

The method used for this study was similar to the meta-analytic techniques suggested by Cooper and Hedges (1994) and Wolf (1986). The use of meta-analytic techniques allows for the comparison of the effectiveness of technology use in statistics education on achievement and attitudes across a large number of studies.

### *Literature Search*

An extensive search of the literature was conducted in order to obtain as many studies as possible that have examined the effectiveness of technology use in statistics instruction. Databases such as *EBSCOhost*, *Educational Resources Information Clearinghouse (ERIC)*, *Dissertation Abstracts International*, and *ProQuest Dissertations and Theses* were used to obtain published and unpublished studies. Searches of *PsycINFO*, and *Educational Abstracts* were also conducted. The keywords used in the search included, "teaching statistics," "statistics education," and "statistics instruction".

### *Inclusion and Exclusion of Studies*

Studies were included in the sample if they meet several criteria. First, the studies must have been conducted on uses of technology to enhance statistics instruction. Also, introductory, intermediate, and advanced statistics courses were included in the meta-analysis, as well as

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quantitative methods courses that were heavily statistical in focus. Second, studies were included if they were conducted using undergraduate or graduate students as participants. Third, the studies were included if the authors used an outcome variable that measured student achievement or student attitudes. Fourth, studies were included in the meta-analysis if a control group was used. Finally, studies were included if effect sizes could be calculated from the information provided in the report.

*Coding of Studies*

Each study was coded according to the following study characteristics: use of technology (e.g., drill and practice, tutorial, simulations, online, etc.), function of technology (i.e., supplemental vs. substitutive), duration, academic discipline, course level (i.e., introductory, intermediate, or advanced), student academic standing, instructor bias, research design, the outcome variable (i.e., achievement or attitude), and publication source. In addition, studies were coded according to several study characteristics, including the year of the study, group means and standard deviations, number of participants in each group, use of a pre-test, and $F$ and/or $t$ values if means and standard deviations were not available.

*Calculation of Effect Sizes*

In order to compare the results across individual studies, standardized effect sizes were calculated (i.e., Cohen's d). If the authors have provided another effect size measure other than Cohen's d, then the effect sizes were converted to Cohen's d using one of the formulas available in Wolf (1986) or Cooper and Hedges (1994).

*Analysis of Research Questions*

The criterion variable for all analysis was the effect sizes obtained in the studies. Analyses were conducted using the Linear Mixed Modeling function in SPSS 21 in order to account for the possibility of multiple effect sizes found within each study. Each study was treated as the subject, and the study variable was included as a random factor. All other variables were treated as fixed factors, and only main effects were examined. Effect sizes were weighted by the inverse of the variance to account for differences in sample sizes across studies.

## RESULTS

A total of 148 effect sizes were obtained from 62 individual articles, covering the years 1974 to 2012. Effect sizes ranged from -1.41 to 2.92 in magnitude. A mean study-weighted effect size of 0.280 was found across all studies and this value was statistically significant, $t$ (62.991) = 4.467, $p < 0.001$. However, considerable variance in effect sizes remained unexplained, Wald $Z$ = 2.99, $p$ = .003, suggesting that the mean study-weighted effect size found when considering all studies was moderated by one or more study characteristics. Further analyses examined the differences in effect sizes across online vs. face-to-face courses, function of technology use (i.e., supplemented instruction or substituted instruction), duration of instruction (i.e., one time use, multiple uses within an academic terms, full academic term or longer), instructor bias (i.e., same vs. different instructions), research design (i.e., randomized vs. non-randomized designs), and publication status (i.e., published vs unpublished studies). The results of the $F$ tests are presented in Table 1. Only the difference in mean effect sizes between online and face-to-face courses was statistically significant, $F$ (91.328) = 8.084, p = .006. The mean difference in the effect sizes between face-to-face and online courses was .452, in favor of face-to-face courses. Mean differences and statistical tests are provided in Table 2.

Table 1. Results of Statistical Tests of Group Differences in Effect Size

| Source | $df_1$ | $df_2$ | *F* | *p* |
|---|---|---|---|---|
| Intercept | 1 | 73.430 | .003 | .953 |
| Function | 1 | 91.628 | .183 | .670 |
| Duration | 2 | 104.368 | .740 | .480 |
| Publication Status | 1 | 50.718 | 1.157 | .287 |
| Research Design | 1 | 79.439 | .000 | .989 |
| Instructor Bias | 2 | 84.300 | 1.879 | .159 |
| Online vs. Face-to-Face | 1 | 91.328 | 8.084 | .006 |

Table 2. Mean Differences and Statistical Tests for Moderator Variables

| Comparison | | | $M_1 - M_2$ | *t* | *df* | *p* |
|---|---|---|---|---|---|---|
| Intercept | | | -.263 | -1.163 | 68.155 | .249 |
| Substitution | - | Supplemental | -.068 | -0.428 | 91.628 | .670 |
| One Time Use | - | Full Semester | .177 | 1.096 | 82.472 | .276 |
| Several Uses | - | Full Semester | -.017 | -0.304 | 132.005 | .762 |
| Unpublished | - | Published | -.162 | -1.076 | 50.718 | .287 |
| Non-randomized | - | Randomized | .002 | 0.013 | 79.439 | .989 |
| Not-specified | - | Different Instructors | .046 | 0.196 | 81.569 | .845 |
| Same Instructor | - | Different Instructors | .268 | 1.738 | 86.462 | .086 |
| Face-to-Face | | Online | .452 | 2.843 | 91.328 | .006 |

## CONCLUSION

This study assisted in compiling evidence that suggests enhancing statistics instruction with technology can be, under certain conditions, a worthwhile endeavor. Certain uses of technology can be modestly more effective than a lack of technology, however, instructors must take great care in introducing technology in a manner that will benefit students most and is most cost effective. However, a great deal of variability remained explained by the factors examined, suggesting that there may be additional variables that moderate the effectiveness of the use of technology on achievement outcomes.

## REFERENCES

Cooper, H., & Hedges, L. V. (1994). *The handbook of research synthesis.* New York: Russell Sage Foundation.

Fernandez, G. C. J., & Liu, L. (1999). A technology-based teaching model that stimulates statistics learning. *Computers in the Schools, 16*(1), 173-191.

Forte, J. (1995). Teaching statistics without sadistics. *Journal of Social Work Education, 31*(2), 204-218.

Given, K. (2005). *The Impact of computer-assisted instruction on student schievement in post-secondary statistics instruction: A meta-analysis*. Unpublished doctoral dissertation, Kent State University; Kent, OH.

IBM Corp. (2012). IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

Johnson, B. T. (1989). *DSTAT: Software for the meta-analytic review of research literatures.*

Khamis, H. J. (1991). Manual computations: A tool for reinforcing concepts and techniques. *The American Statistician, 45*(4), 294-299.

Schenker, J. (2007). *The effectiveness of technology use in statistics instruction in higher education: A meta-analysis using hierarchical linear modeling*. Unpublished doctoral dissertation, Kent State University; Kent, OH

Wolf, F. M. (1986). *Meta-analysis: Quantitative methods for research synthesis*. Newbury Park, CA: Sage.