Paper Title Impact of Innovative Technology-Related Interventions on K–12 Students' STEM Career-Related Outcomes: A Meta-Analysis

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Purpose of the Study

As elucidated in “10 Big Ideas for Future NSF Investments” (nsf.gov, nd), future generations of STEM-capable professionals will continue to be a key sector of the U.S. workforce. Federal, state, and local workforce investments are intended to improve the education and preparation of a STEM workforce that will be ready to capitalize on advances in technology and science. Additionally, national strategic goals for broadening students’ participation in STEM careers is central to ensure that students who have been historically underrepresented and underserved in STEM have access to and are equitably included in the STEM career pipeline. Public and private sectors agree that the U.S. does not develop a sufficient number of or sufficient diversity in individuals who are prepared for and interested in pursuing STEM careers. The report from a panel of Fortune 500 companies stated that U.S. initiatives to address the lack of STEM diversity have been disappointing, resulting in not only a lack of diversity, but also a decline in the number of engineering and computing workers under the age of 25, 25% and 15%, respectively, since 2001 (Clark & Esters, 2018). Further, while the proportion of Whites and Asians comprising the U.S. STEM workforce has decreased, they still occupy a majority of STEM positions, holding 87% of the engineering positions and 84% of computing technology positions (Pew Research Center, 2018). Given the importance of technological expertise to current and future STEM career preparation, this study of interventions using innovative technology provides timely insights about the impacts of technology-rich experiences on STEM career outcomes for all students.

The primary objective of this meta-analysis study is to review and synthesize research and evaluation findings demonstrating the effects of integrating innovative technologies and technology-based learning experiences in STEM education on K-12 students’ STEM career outcomes. This study synthesizes the rigorous intervention research on Grades K-12 students’ STEM career-related outcomes from 1995 to the present and across characteristics of technology-based STEM education interventions, learning contexts, student demographics, and study designs. This study develops an understanding of the extent to which the effects of technology-based STEM education interventions are different for students who are traditionally underserved and underrepresented in STEM education. Meta-analysis techniques also allow for control of the moderator effects of study rigor and publication biases.

This study responds to the following research questions:

1. What are the magnitudes and variations of effects of integrating innovative technologies into K-12 STEM education on students’ career outcomes?
2. How are the magnitudes and variations of these effects different for students underrepresented in STEM?

3. If and to what extent do intervention characteristics, educational settings, and primary study methodological features moderate the impact of integrating innovative technologies into K-12 STEM education on students' career outcomes?

Theoretical Framework

This study builds upon the work of the STEM Learning and Resource Center (STELAR), to test assumptions of the conceptual model developed to visualize relationships among components of the innovative technology-related interventions and anticipated career outcomes for students. This study considers three of the five elements embedded in the model developed by LRC: (a) STEM career development activities, (b) educator professional development, and (c) project cultural context (Reider, Knestis, & Malyn-Smith, 2016). In their thorough review of federally-funded innovative technology-related education projects and subsequent case study of a sample of projects which differed in topic, content, setting, and design, STELAR found that current research and evaluation on these projects focused primarily on changes in students' content dispositions, knowledge, and skills and not on career-related outcomes. They concluded that, "Findings about the link between these workforce-directed projects and workforce education outcomes could be more robust" (Reider et al., 2016, p. 857). One of their recommendations was to conduct studies focused on STEM career and workforce education components to link the influence of innovative technology-related interventions with students' motivation to pursue STEM and participation in the STEM workforce.

This study fills gaps in knowledge that leads to a better understanding of the impact of initiatives employing innovative technologies and technology-based learning experiences than is currently available. The STEM Workforce Development Model proposed by STELAR suggested that effective teaching and learning actions by educators promotes STEM career development of students leading to persistence in STEM learning and entry into STEM careers (Reider et. al., 2016). This current study mines the substantial body of data, research, and evaluation findings that are primarily focused on educational components such as STEM curriculum, content knowledge, and teacher professional development outcomes with the singular purpose of identifying and quantifying how integrating innovative educational technologies and technology-based learning experiences in K-12 classrooms impacts the career outcomes of students. This study is firmly grounded in and extends knowledge advanced by the current body of meta-analytic studies regarding outcomes of student STEM career development. Recently-published meta-analysis studies have investigated the impacts of career choice interventions on career outcomes (Whiston, Li, Mitts, & Wright, 2017); the relationship between sources of self-efficacy and STEM efficacy beliefs (Sheu et al., 2018); the relationship between environmental barriers and supports and career development (Brown et al., 2018); correlates of career goal outcomes for Latino/a students (Risco, O'Brien, Grivel, & Castro, 2019); and the impacts of innovative mathematics and science teaching on science career interest (Savelsbergh et al., 2016). These studies have included some elements of interest to the current study—such as a focus on career outcomes and career outcomes for underrepresented populations—but this study investigates the links between STEM interventions and STEM career outcomes, directly.

Methods and Data Sources

The method for conducting this study follows steps common to meta-analysis. As this project re-synthesizes the studies included in Means et al. (2013) using network meta-analysis, the first step is to locate empirical studies for the meta-analysis.

1. Eligibility Criteria and Study Selection

This study identifies key terms for each of the targeted constructs regarding participants, interventions, comparison condition/study design, outcomes, and settings (PICOS). Guided by the research questions, a primary study is included in the meta-analysis if its PICOS meet the following screening criteria:

Participants. Study participants must be K-12 students or school-aged children who received direct or indirect STEM-related education interventions in the United States. This project only reviews and synthesizes studies conducted in the U.S. because the cultural and socio-economic context of formal and informal STEM education in the U.S. is unique among Western countries and likely has a significant impact on students' STEM career-related outcomes. A participant indicator was created to separate studies exclusively reporting on an underrepresented student subpopulation (e.g., female African American students) from those which did not target a specific subpopulation. This variable was considered as a moderator.

Interventions. This meta-analysis includes studies focusing on a broad-range of interventions designed to improve STEM teaching or learning with innovative technologies. The researchers retrieved intervention content areas, intervention pedagogical practices, intervention durations (e.g., implemented for a unit, a semester, a year, or multiple years), and whether the intervention consisted of an explicit career development component (e.g., career counseling), from the primary studies. Intervention characteristics are coded as moderators for this analysis.

Comparison Condition/Study Design. For inclusion in the meta-analysis, the primary study must be an empirical study that explicitly measures STEM career-related outcomes following an intervention meeting the aforementioned criteria. This study includes primary studies with Randomized Controlled Trials (RCT), Regression-Discontinuity Designs, Quasi-Experimental Designs (QED) with control for baseline equivalences, and observational studies with pre-post measures that did not include a control or comparison group. Types of design, intervention duration (i.e., time between pre- and post-measurements) and publication type (peer-reviewed publications vs. gray literature) were coded as moderators.

Outcomes. This study utilizes a broad definition of "career outcomes" in order to capture any study that should be included for meta-analysis. Following the work of STELAR scholars, STEM career-related outcomes are coded into four categories (a) dispositions, (b) knowledge, (c) skills, and (d) actions (Reider et al., 2016). For example, attitude toward STEM careers is categorized as a disposition outcome, whereas career exploration is an action outcome.

Settings. This study includes primary studies conducted in formal settings or informal, out-of-school settings. Community contexts in which interventions were conducted include traditionally underserved communities. Intervention settings and community contexts were coded as moderators to understand the how educational settings moderate the magnitude of intervention effects.

2. Search Strategy

This study includes primary studies published since 1995 that meet the search criteria. Databases searched include ERIC via EBSCOHost, Education Research Complete via EBSCOHost, and APA PsycINFO via EBSCOHost. In addition, STELAR Resources and ProQuest Dissertations and Theses are used to search grey literature.

3. Screening for study inclusion

Screening steps include title and abstract screening, deduplication, full text retrieval, and full text reviews, based on the PICOS eligibility criteria. To ensure reliability, each screening step is conducted by at least two researchers. Endnote is used to keep track of each stage of the review process.

4. Coding and Effect Size Calculation

Because the focus of this study is on the variation of effect sizes across studies, modified by students' demographic background; intervention characteristics; education settings; and study design, it is critically important to include information about the process of coding the included primary studies and the content of the codes used. Coding for this study is based on a living codebook developed following Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Green, 2011) and Campbell Systematic Reviews: Policies and Guidelines (The Campbell Collaboration, 2019). Each primary study is coded by at least two researchers to ensure reliability. Design equivalent effect sizes are calculated for effects from single-group pre-post designs, two-group pre-post designs, and clustered RCT designs.

5. Data Analysis

R package metafor is used to conduct the meta-analysis to pool the estimated effect sizes (bias-corrected Hedge's *g*) across studies to 1) estimate the overall average effect sizes and average effect sizes for interventions explicitly targeting underrepresented students; 2) calculate the amount of heterogeneity in effect sizes; and 3) determine moderator effects. Multivariate random-effect model using restricted Maximum Likelihood (REML) estimation and inverse variance weighting provides estimates of average effect size of the eligible studies, its variation, 95% prediction interval (Borenstein, Higgins, Hedges, & Rothstein, 2017), and other heterogeneity statistics while taking dependency of multiple effect sizes into account.

Preliminary Results

This preliminary analysis includes 34 effect sizes from 26 primary studies spanning 1995 to 2020 (*N* = 7781). For all career-related outcomes, the weighted average effect was *g* = 0.178 (95% CI [.061, .295], with 22 positive effects, 2 negative effects, and 6 zero effects (i.e., the absolute value < 0.1). Tau-squared estimates indicates no evidence of significant heterogeneity.

The majority of career-related outcomes (74%) are categorized as disposition (e.g., STEM career interest), followed by career skills (21%) and knowledge (6%). Moderator analyses indicated that interventions targeted high school students had larger impacts on their STEM career-related outcomes than did those targeted elementary or middle school students. The programs aiming at serving students from backgrounds that are traditionally underrepresented and underserved in STEM education had slightly higher impacts than programs served general student populations. One expected finding was that programs with explicit career-exploration component had slightly smaller impact than those without such components. No evidence of moderation was found for education settings (formal/informal education), intervention duration, study design, and publication type.

Significance of the Study

This study contributes substantive, essential knowledge to (a) advance understanding of the effects of integrating innovative educational technologies and technology-based learning experiences in K-12 classrooms on students' STEM career outcomes, (b) enable generalization of the magnitudes and variations of effects on students, (c) specify what innovative technologies and technology-based STEM interventions have been effective for which groups of students and in what settings, and (d) provide insight to how and why such interventions produced positive outcomes. This comprehensive study can potentially have immediate impact on development and evaluation of educational initiatives and technology-driven workforce development projects, as well as inform a future research agenda.

Reference

Beretvas, S. N. (2010; 2019). Meta-analysis. In G. R. Hancock & R. Mueller (Eds.) The Reviewer's Guide to *Quantitative Methods in the Social Sciences* (pp. 255-263). New York: NY: Routledge.

Borenstein, M., Higgins, J. P., Hedges, L. V., & Rothstein, H. R. (2017). Basics of meta-analysis: I2 is not an absolute measure of heterogeneity. *Research Synthesis Methods, 8*(1), 5-18.

Brown, S. D., Roche, M., Abrams, M., Lamp, K., Telander, K., Daskalova, P., & Massingale, M. (2018). Relationships among supports and barriers and career and educational outcomes: A meta-analytic investigation. *Journal of Career Assessment*, *26*(3), 395-412.

Clark, Q. M., & Esters, L. T. (2018, July 24). *Federally Funded Programs Are Not Enough to Diversify the STEM Workforce*. Retrieved from https://diverseeducation.com/article/120618/

Hedges, L.V., Tipton, E., & Johnson, M.C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods, 1*(1): 39-65. Erratum in 1(2): 164-165.

Higgins, J. P. T., & Green, S. (Eds). (2011). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0* [updated March 2011]. The Cochrane Collaboration, www.handbook.cochrane.org.

Reider, D., Knestis, K., & Malyn-Smith, J. (2016). Workforce education models for K-12 STEM education programs: Reflections on, and implications for, the NSF ITEST program. *Journal of Science Education and Technology, 25*(6), 847–858. https://doi.org/10.1007/s10956-016-9632-6

Risco, C. M., O'Brien, K. M., Grivel, M. M., & Castro, J. E. (2019). A meta-analysis of the correlates of educational and vocational goals for Latina/o students. *Journal of Career Assessment*, *27*(1), 29-46.

Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review*, *19*, 158-172.

Sheu, H. B., Lent, R. W., Miller, M. J., Penn, L. T., Cusick, M. E., & Truong, N. N. (2018). Sources of self-efficacy and outcome expectations in science, technology, engineering, and mathematics domains: A meta-analysis. *Journal of Vocational Behavior*, *109*, 118-136.

STEM Learning and Research Center (STELAR) Resource Website (n.d.). Retrieved from http://stelar.edc.org/resources

The Campbell Collaboration. (2019, January 10). Campbell systematic reviews: Policies and guidelines. Campbell Policies and Guidelines Series No. 1. DOI: 10.4073/cpg.2016.1

Whiston, S. C., Li, Y., Mitts, N. G., & Wright, L. (2017). Effectiveness of career choice interventions: A meta-analytic replication and extension. *Journal of Vocational Behavior*, *100*, 175-184.