International Journal of Gender, Science and Technology
http://genderandset.open.ac.uk

A Synthesis of Practice-Oriented Literature in Gender and Stem

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ABSTRACT
Even as endorsement for the idea of "evidence based practice" has become widespread, there has been little headway to find an empirical way to gauge whether models for best practice put forward in practice-oriented literature are warranted. This research addressed questions about trends over time in both the quantity and quality of the evidence base of articles describing activities initiated to promote the recruitment of retention of women and girls in STEM. Practice-oriented publications (n=142) were identified from a larger database (N=976) of articles with references to gender and STEM in the title or abstract. A six-point ordinal scale was used to measure the quality of the foundational or evidence base of the articles. Between 1995 and 2009, the percentage of articles meeting the threshold definition of being evidence-based grew from 43.8% in the first time period, to 49.3% in the second time period, and to 59.6% in the most recent time period. The relatively recent expansion of the digital infrastructure that supports the dissemination of STEM-related publications, promises to minimize redundancy and to ensure that resources are invested in initiatives where there is evidence to support its potential to be effective.

KEYWORDS
Keywords: Evidence based practice, content analysis, gender and STEM

Rhetoric placing priority on evidence-based practice increased after the passage of the No Child Left Behind Act in 2001 (Slavin, 2002). This marked a shift in emphasis on testing and instruction directed by standards of learning in primary and secondary schools in the United States. "Evidence-based practice is generally defined as the conscientious, explicit, and judicious use of information to serve as the foundation for practice" (Sandelowski, Voils, & Barroso, 2006). Undergirding the rhetoric is strong endorsement for the idea that practices that advance educational goals should be designed with grounding in research that supports its potential to be effective. Although the discourse has been heavily shaped by its application to clinical or medical settings, the parlance of evidence-based practice now extends to other fields and beyond the limitation of a single experimental research design (Slavin, 2002).

Endorsement for evidence-based best practice weaves throughout the merit criteria of national funding agencies in the U.S., including the National Science Foundation (NSF), the National Institute of Health (NIH), and the Department of Education (Slavin, 2002). High quality initiatives are expected to be replications or extensions of smaller scale pilot studies and to be designed with grounding in evidence that supports the potential for the practice to be effective (Stricker, 2003). The demand for the grounding of proposals in systematic reviews of empirical research is at the heart of evidence-based practice (Sandelowski et al., 2006).

Documentation of the foundational grounding, including for reports about outreach efforts, is an important dimension of comprehensive frameworks designed to evaluate quality in scholarly publications. The foundational element documents the feasibility of an intervention and how it is linked to prior knowledge and research (American Educational Research Association, 2006). Without such grounding, it is not possible to determine its contribution to knowledge (Beach, Becker, & Kennedy, 2007).

Practice-oriented publications are part of the body of literature designed to report on the effectiveness of initiatives designed to promote interest in science, technology, engineering, and math (STEM). I define a practice-oriented publication as one that states that its principal purpose is to describe the design, delivery, and outcomes of educational activities, classes, or programs in K-12 or at the collegiate level. A key assumption of the evidence-based movement is that the potential for a program or activity to achieve its desired outcomes is enhanced when it has been designed by leveraging lessons learned from similar initiatives and that such lessons are generalizable across settings.

Practice-oriented publications have long been a fixture in the literature that shares as its goals that intent to promote the retention of success of students and faculty in STEM. Brown (2012) calculated that practice-oriented publications account for about 20% of articles appearing in STEM education journals. They are part of what Darke et al. (2002) identified as the knowledge capital or infrastructure of a field. When appearing in peer reviewed scholarly outlets or vetted at academic conferences, publications about informal and formal activities designed to promote interest in STEM are taken to contribute to the generation of new knowledge and to

be worthy of replication in other settings. This is the case regardless of how effective the authors were in linking the way the intervention was designed with the knowledge base, or in providing evidence that the effectiveness of at least some elements of the practice had been substantiated in other settings.

This examination of trends in practice-based STEM articles provides a way to assess quality and to accumulate evidence to determine if the field can be said to be moving forward or maturing. Andrews and Harlen (2006) maintain that a mature field is paradigmatic in that there is broad consensus about strong unifying theories. An alternative conclusion, as Davies (1999) has charged, is that education, like some other applied fields that are not resource rich, lacks the infrastructure to support the development of a body of knowledge that is cumulative, rather than idiosyncratic or repetitive.

This paper reports on the results of a content analysis that assessed trends over time (1995-2012) in the quality of the foundational element of articles describing informal programs, activities, workshops, or courses initiated to promote the recruitment or retention of girls and women in STEM. ~~Content analysis – also referred to as a systematic review - is a research method that involves the use of a systematic classification process to code textual data (Hsieh & Shannon, 2005).~~ Systematic reviews are guided by research questions and develop systems to score articles using both qualitative and quantitative analysis (Andrews & Harlen, 2006). ~~The~~ research addressed questions about both the quantity and quality of this sub-set of the body of literature about gender and STEM.

The following research questions guided the study:

1. Has there been a significant increase in the number of practice-oriented gender and STEM articles appearing between 1995-2012?
2. Is there a statistically significant increase in the foundational quality of gender and STEM practice-oriented articles between 1995-2012?

The analysis reported in this article was conducted with support from the Gender in Science and Engineering (GSE) Program at the U.S. National Science Foundation (NSF GSE 0832913). The grant was designed to collect data to assess the impact of program funding on the quality of publications. The second goal was to contribute to the infrastructure in the field of gender and STEM by creating a set of visualizations to synthesize trends in the literature and to provide public access to a database of gender and STEM articles published between 1995 and 2012. This database is now available through the Women in STEM Knowledge Center hosted by the Women in Engineering Proactive Network (WEPAN) (http://www.wskc.org/ttgsp-visualizations). I have been publishing research about issues related to gender and STEM since the early 1990s. I consider my familiarity with the body of literature as an asset in the synthetic research I am reporting in this article.

The size of the database made it possible to use statistical procedures to evaluate multiple dimensions of the quality of these articles and to assess if the knowledge

capital in the field of gender and STEM could be said to be moving forward in that the quality of newer initiatives improved as they reflected increasing knowledge of previously produced literature. The study was launched with the hypothesis that because of the rhetoric about evidence-based practice emerging after 2001, the foundational quality of practice-oriented articles would increase significantly over time.

LITERATURE REVIEW

Interest in the specialized topic of gender and participation in STEM fields emerged at about the same time that early feminist academics began to explore the visibility of gender issues in bodies of literature in various disciplines (e.g. Dubois et al., 1985; Lockheed & Stein, 1980; Russ, 1983). At the same time, several policy initiatives have been attributed with providing the impetus for the growth of research about women in STEM. It has only been recently, however, that the infrastructure has become strong enough to make it possible to synthesize the large and continually growing body of literature dealing with gender across the diverse STEM fields.

The onset of growing interest in topics related to gender and STEM can be attributed to feminist activism. In Europe it has been marked by several policy initiatives, including the 2013 white paper produced by the European Research Council, "On the Way to the Top: Providing Equal Opportunities for Men and Women in Science and Technology" summarizing conclusions from a conference by the same name held in Brussels. In the U.S., the passage of the Technology Equal Opportunities Act in 1980 mandated that the National Science Foundation (NSF), a major federal governmental funding agency, expand the infrastructure about gender by tracking data on the status of women and minorities in the science and engineering professions and reporting it to Congress (Rosser & Lane, 2002). Interest in gender and STEM in the U.S. was further spurred by the inauguration in 1993 of a gender-focused funding opportunity at NSF, the Program for Women and Girls (PWG)[1] and shortly thereafter, in 1994, of the first interdisciplinary journal to focus on gender and STEM, the *Journal of Women and Minorities in Science and Engineering* (JWMSE). Between 1993 and 1996, PWG invested $37 million in research and programs that explored factors and climate issues that deterred women from careers in science and engineering (Darke et al., 2002). As will be seen in the results presented below, trends in the overall number of gender and STEM publications correspond with many of the dates of these key policy initiatives.

At least two sets of authors have previously undertaken the task of providing a systematic review of the literature about gender and STEM. Ceci and Williams (2010) provide an example of such a review that synthesized more than 400 articles about gender differences in math. Fox and her colleagues (2012) presented a poster at a meeting of the National Science Foundation that showed the results of a preliminary synthesis of the body of gender and STEM journal articles across disciplines. Fox and her team only reviewed articles from journals that are indexed by the Web of Knowledge. Their search yielded 3,053 out of 23,000 (13%) relevant

publications over a 44-year time span (1966–2010). Preliminary results from their analysis showed that the number of gender and STEM related publications started to grow exponentially after the early 1990s and that these publications were widely dispersed in a variety of journals and disciplines.

Results from the first phase of this research project were consistent with what others have reported about the presence of practice-oriented publications in the body of literature about STEM. Early phases of a research project funded by the National Science Foundation (NSF) and that was designed to synthesize different aspects about publications dealing with gender and STEM, revealed that between 1995 and 2009 practice-oriented articles accounted for 23.2% of articles (142 of 612) appearing in multiple sources (Mutcheson, Sutherland, & Creamer, 2013). This is comparable to the 20% reported by Brown (2012) for STEM education journals. A much smaller percentage of practice-oriented publications (34 of 276, 12.3%) appeared in the *Journal of Women and Minorities in Science and Engineering* (*JWMSE*) than in the proceedings of publications from two engineering education related conferences (32.6% in proceedings of American Society of Engineering Education conferences; 30% of proceedings of the Frontiers in Education [FIE] conference).

Analysis of high-scoring articles (n=24) during the qualitative phase of the study revealed several additional features of the way the problem was framed in the introduction (Mutcheson et al., 2013). Fourteen of the 24 explicitly referred to a theoretical framework. Twenty-two of the 24 explicitly linked the way an intervention had been designed with beliefs about the root causes of the historically long-standing under-representation of women in STEM fields. There was not consensus among the authors, however, about the root causes for the persistent under-representation of women in disciplines like computer science.

METHODS

In this section, a description is provided of how the database of articles was assembled and the scale constructed to score the foundational quality or evidence-base of the practice-oriented articles identified from the larger database in the first phase of its development. Analytical procedures are also explained.

Creation of the Database

A database of gender related publications was created in accordance with the stipulations of a NSF grant designed in part to develop measures to assess the impact of the GSE program on the knowledge base in gender and STEM. In order to achieve this, an Excel database of articles was built and coded in two consecutive steps that began in the summer of 2012 and ended in the fall of 2014. Keyword searches were conducted of various publication venues and the ISI Web of Science to identify articles using the search terms [gender or female or girl or women or gender] and [science or engineering or technology] in the title or abstract.

In the first phase of data collection during the summer of 2012, the search terms were applied to identify all articles related to gender and STEM appearing in four peer-reviewed sources that reach an audience of engineering educators. These were the *Journal of Women and Minorities in Science and Engineering* (JWMSE), proceedings from the American Society of Engineering Conference (ASEE) and Frontiers in Education (FIE) conference, the *Journal of Engineering Education* (JEE) and the *International Journal of Engineering Education* (JEE). The initial search was conducted for the time period 1995-2009 (N=612). [2]These journals were targeted in the first phase of data collection because an analysis of annual reports from GSE funded projects revealed that these were the most frequent publication venues for grant-related publications and because much of the research produced by engineering educators appears in the form of conference proceedings.

In the second phase of the project, the search for related articles was expanded to incorporate gender and STEM articles appearing in other digitally accessible journals searchable through the ISI Web of Science. Phase 2 yielded an additional 214 articles (N=826) and added publications appearing between 2010 and 2012 from JWMSE and more sources including the *European Journal of Engineering Education* and *the Journal of Science Education and Technology*. A colleague extracted an additional 150 non-duplicated publications from annual reports submitted by principal investigators from the Gender in Science and Engineering Program (GSE), bringing the total number of publications in the database to 976 and introducing a small number of publications appearing in 2012. Most of these publications are now accessible to the public through the Women and STEM Knowledge Center hosted by WEPAN. Books are not included in the database, nor editorials or speeches. There is some selection bias in the database in that all JWMSE articles published between 1995 and 2012 were included in the database. We only had the resources to extract the list of publications produced by projects funded by the gender-focused program at the U.S.-based National Science Foundation, the Gender in Science and Engineering Program. Only one international journal was included, the ~~*Journal of Engineering Education*~~.

Each article was coded for nine different variables and the data entered in a database initially maintained in Excel. After authors names and additional bibliographic information was entered, each article was coded for these variables: three keywords; if the article acknowledged support from funding and, if so, from where; if the sample included members of other under-represented groups and, if so, what groups; the STEM discipline(s); the nature of the sample (e.g. K-12 students, K-12 teachers or other personnel, undergraduate students, community college students, etc.); the institutions involved (single, home; single, not home; multi-institutional); and the type of publication (research, practice, literature review, theoretical or conceptual). Articles coded as research were also coded for method (qualitative, quantitative, or mixed). This coding is now part of the search terms that can be used to access the articles in the database now housed in the Women in STEM Knowledge Center.

The analysis reported in this paper was conducted with all of the practice-oriented articles (N=142) that were coded during the initial phase of assembling the database in the summer of 2012. Research-based and practice-oriented publications were distinguished in terms of the stated purpose of the publication. Practice-oriented publications were identified as those that that had among their stated purpose the intent to describe the design, delivery, and outcomes of an educational activity, class, or program in K-12 or at the collegiate level. Articles showing the results of statistical analysis beyond descriptive data about participants and basic measures of satisfaction were classified as research articles. It is possible that many of the practice-oriented publications, particularly those appearing as conference proceedings, may have been prepared early in the implementation of projects and prior to the analysis of a significant body of data.

Development of the Quality Measure

Matching my curiosity about the extent that practice-oriented articles in STEM could be characterized as evidence based, I developed a quality measure to evaluate the foundational element of each article. The foundational element is part of the problem formulation and "reflects the researchers' prior understanding of a construct and/or phenomenon under study" (Dellinger & Leech, 2007, p. 323). Evidence of prior understanding comes in the form of a theoretical framework, analysis and evaluation of research related to the construct or phenomenon, and/or reflections about personal experience or understanding (Dellinger & Leech, 2007). While this may be more a goal than a reality for many practice-oriented publications, the standards of the American Educational Research Association (AERA) (2006) specify that when a report involves practice, authors should be explicit about how the practice addresses the identified concerns.

After reviewing articles about standards for evaluating educational scholarship, such as those disseminated by AERA, I used a deductive approach to develop a six-point ordinal scale to evaluate the foundational quality of practice-oriented publications. The scale was operationalized and refined during a pilot study when several students helped test its efficacy by using it to code 25 practice-oriented articles randomly selected from the larger database. During the pilot study, three scorers continued to meet and compare scores until three-way inter-rater reliability was consistently in excess of 90%. Two of these students then went on to score each of the remaining practice-oriented publications. During the coding, they focused on explicit language provided in the text, but exercised judgment in evaluating the relevance and quality of the references cited to support an innovation. References to Internet websites or Google were excluded, for example, from the final counts of supporting references. Confirmation of the validity of the scale came from an in-depth qualitative analysis of the high-scoring articles (cites blinded for review).

Analysis

Appendix 1 replicates the coding sheet that was used to score practice-oriented articles. It shows the definition of each of the criterion and the score that was awarded for each criterion.

For the analysis, quality was measured as a dichotomous variable and analyzed

used Chi-Square. Based on guidance from the literature about the characteristics of evidence-based practice, I interpreted a score of 4, 5, or 6 to warrant the designation of being evidence-based, while a score of 3 or less was not. Chi-square is the appropriate statistical procedure for use with ordinal data.

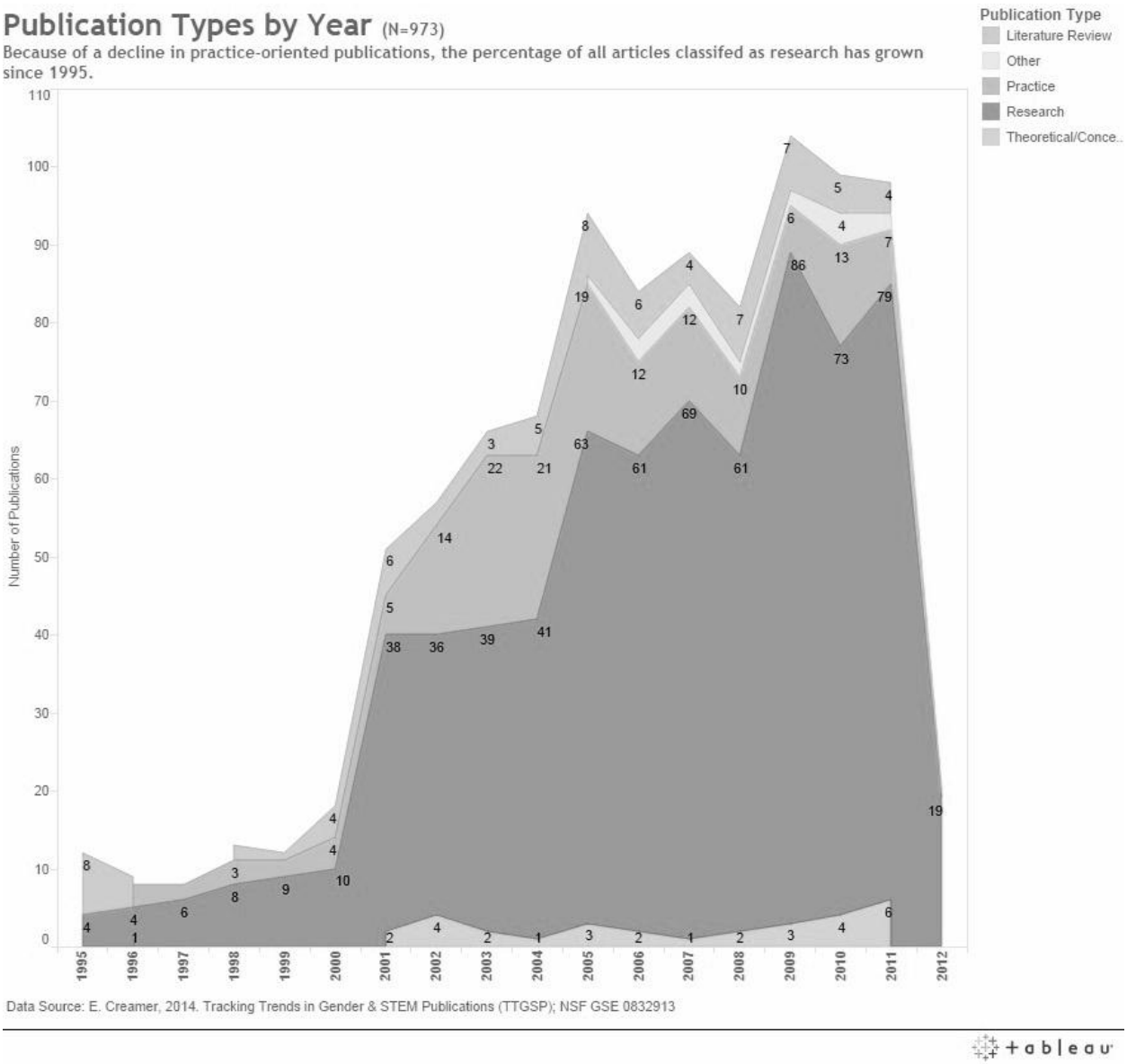
RESULTS

Results from the analysis for each of the two research questions are presented in this section. The first question examined trends in the quantity of all types of publications over time (1995-2012), which emerged from the final database completed in 2014. Data are also provided about the publications venues. The second research question focused on quality and used data from the coding of the sub-set of practice-oriented articles published between 1995-2009.

Research Question 1: Trends in the Number of Gender and STEM Articles Since 1995

Figure 1 provides a stacked bar graph showing the representation of each of all types of publications that were coded in the database (N=973). Total number of publications is shown along the vertical axis, while years are displayed across the horizontal axis. This and other visualizations are available through the Women and STEM Knowledge Center (http://www.wskc.org/ttgsp-visualizations).

Figure 1: Publication Types by Year (1995-2012)



The stacked bar graph visually demonstrates that it is no longer accurate to say that there has been little research about gender issues in STEM. The stacked bar graph shows the explosive growth in the total number of publications being produced after 2000, particularly in research articles. About 10 articles a year were produced between 1995 and 1999. This number expanded to about 20 per year by 2000. Following that, there was a dramatic spurt in the total number of articles produced per year between 2001 and 2005 (from 50 in 2001 to 90 in 2005). That was followed by a dip in number of articles in 2006 to 2008, and then a return in 2009 to the appearance of about 100 articles a year.

The wide dispersion of the literature across different journals is evident by the fact that publications appeared in 147 different journals. Other than the five sources indexed in the first phase of the analysis, the largest number of gender and STEM focused articles appeared in the *European Journal of Engineering Education* (n=21),

Journal of Science, Education, and Technology (n=15), Gender and Education (n=13), *CBE-Life Sciences Education* (n=11) and *Minerva: A Review of Science and Learning* (n=7). Numerous practice-oriented articles, including at least 14 case studies that have appeared in the International Journal of Gender, Science and Technology (*IJGST*), were not identified because the search was conducted through the Web of Science, rather than through Google Scholar. A full list of publication venues with five or more articles appears can be accessed through: www.wskc.org**.**

Table 1 provides a detailed breakdown of the number of gender and STEM related articles by type and time period (1995-2012) over the two phases of data analysis.

Table 1: Summary of Trends in Gender and STEM Related Publications Types by Time Period (N=976)

PUBLICATION TYPE	TIME FRAME				**TOTALS**
	1995-1999	2000-2004	2005-2009	2010-2012	
Literature Review	12 *(22.22%)*	20 *(7.78%)*	30 *(6.73%)*	8 *(3.65%)*	**70** *(7%)*
Practice	10 *(19%)*	66 *(26%)*	60 *(13%)*	21 *(10%)*	**157** *(16%)*
Research	31 *(57%)*	163 *(63%)*	334 *(75%)*	168 *(77%)*	**696** *(71%)*
Theoretical/ Conceptual	1 *(2%)*	8 *(3%)*	11 *(2%)*	9 *(4%)*	**29** *(3%)*
Other	*(0%)*	*(0%)*	11 *(2%)*	13 *(6%)*	**24** *(2%)*
Total	**54**	**257**	**446**	**219**	

The data shown in Table 1 present a different picture of the proportion of practice-oriented publications in the larger knowledge base than earlier reports (Mutcheson, Sutherland & Creamer, 2013). As compared to the earlier time span (1995-2009) when practice-oriented articles were found to account for 23.2% of all articles (142 of 612), they accounted for 16% of all the articles in the final database with the wider time span (1995-2012). This is very likely to be attributable to the fact that more than half of the articles analyzed in the first phase of the research came from conference proceedings (336 of 612).

The pattern of production of practice-oriented publications follows some of the peaks and valleys depicted in Figure 1. While almost non-existent prior to 2000,

this type of publication has grown to become a steady presence in the knowledge base ever since. This type of article was the most sizable part of the literature during the 2000 to 2004 time period where it represented 26% of all publications (N=257). The number dropped to an average of 11.5% in the more recent time periods.

Research Question 2: Trends in the Evidence-Base of Practice-Oriented Articles

The second research question addressed differences in quality in the publications by the four peer-reviewed sources from the first phase of data collection. Given the strong public acceptance for the idea of evidence-based practice, as well as the growth in the body of related publications, I anticipated that the foundational quality of practice-oriented publications would improve over time.

Table 2 provides the results of a Chi-square analysis of the practice-oriented publications (N=142). This only included articles coded during the first phase of data collection. This was used to compare the percentages of practice-oriented publications from phase one that met the threshold definition of being evidence-based by three time periods. I considered a score of 4, 5, or 6 to warrant the designation of being evidence based, while a score of 3 or less was not. Articles scoring at the higher end of the scale documented one or more of the following characteristics in the abstract or introduction to the article: (1) that the decision to implement the activity was based on data, (2) that the decision to implement the activity was supported by a pilot study or was a scale-up of a similar initiative in another setting, or (3) provided explicit references to a theoretical framework to support the rationale for the activity.

Table 2
Chi-Square Procedure: Percent of Articles Qualifying as Evidence Based by Time Frame (N=142)

			Evidence-Based		
			No	Yes	Total
Time Frame	1995-1999	Count	9	7	16
		% within Time Frame	56.3%	43.8%	100.0%
	2000-2004	Count	35	34	69
		% within Time Frame	50.7%	49.3%	100.0%
	2005-2009	Count	23	34	57
		% within Time Frame	40.4%	59.6%	100.0%
Total		Count	67	75	142
		% within Time Frame	47.2%	52.8%	100.0%

Chi-square Test Statistics

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.943[a]	2	.379
Likelihood Ratio	1.950	2	.377
N of Valid Cases	142		

0 cells (.0%) have expected count less than 5. The minimum expected count is 7.55.

Across time, 52.8% of the articles met the definition of being evidence based. While the increase across the three time periods was not statistically significant, the percent of articles that met the threshold definition of providing an evidence base for the intervention increased steadily across the three time periods. The percentage of articles meeting my definition of being evidence-based grew from 43.8% in the first time period, to 49.3% in the second time period, and to 59.6% in the most recent time period. More than 35% of the articles (n=50; 35.2%) supplied three or more citations supporting the choice of an activity and included documentation to show that data on the effectiveness of the intervention was considered at the time of the decision to implement. Almost seventeen percent (16.9%) indicated that the article was reporting on a scale up of a pilot study of a similar intervention. Very few articles explicitly identified a theoretical framework to justify their choice of activity to implement.

DISCUSSION

This research adds to the work of Fox and her colleagues (2012) by exploring questions about advances over time in the methodological quality of one segment of the body of literature about gender and STEM. That is the subset of the literature dealing with the implementation of in- and out-of-the classroom initiatives designed to promote the recruitment and retention of women in STEM fields. This research adds to Fox et al.'s work by including conference proceedings and by focusing on a way to measure quality. The hypothesis was that the foundational grounding or evidence base of these publications would improve over time as the pool of relevant articles expanded and their accessibility through electronic means became more feasible. I also anticipated that the re-shaping of professional standards for empirical research that emerged in response to the emphasis placed on clinical trials and quantitative analysis spurred by the passage in the U.S. of the No Child Left Behind Act (Eisenhart & Towne, 2003) would trigger improvements in the quality of the infrastructure and knowledge base.

Results from the analysis reported on in this paper provide only modest support for the hypothesis that the quality of practice-oriented articles became more evidence based over time. While the percentage of articles qualifying as evidence based increased from 43.8% to 59.6% between 1995 and 2009, the increase was not statistically significant. Only about one-third of the articles provided documentation that an initiative was launched after a systematic review of the empirical research or with data from a small pilot study that supported its potential to be effective. Documentation of theoretical support for why an intervention had the potential to achieve its stated goals, was the quality dimension least likely to be present in the

publication.

There are multiple possible explanations for the failure of many authors of practice-oriented publications to document the grounding of their idea for a new practice or innovation in a body of evidence. It is possible that space limitations, particularly in conference proceedings, could account for the limited attribution to research and theory to support the intervention. Many of the initiators of the activities described in a practice-oriented publication are likely to be practitioners or academics with highly specialized disciplinary expertise in a STEM field, but little experience with the conventions for conducting and executing social science research. Inconsistency in the stringency of the peer review process, particularly when the submissions are for a conference presentation, may also well explain other differences in quality.

It could be charged that the call for evidence-based practice and the demand for evidence to support the potential for an innovation to be effective, particularly when it is conceived with the goal of securing external resources, could in fact have the unintended consequence of suppressing innovation. This effect would be magnified for innovations that are so context and time-specific that duplication in other settings would not be feasible. Rather than suppressing the potential to be innovative, leveraging lessons learned from similar projects in diverse settings can not only improve the potential for practice to be effective, but enhance the understanding of the type of contexts where there is the greatest potential for it to be effective.

CONCLUSIONS

Concerns raised in the 1980s by an earlier generation of feminist academics, (e.g. Creamer, 1994; DuBois, et al., 1985; Russ, 1983), may be part of the impetus that lead not only to legislation and a program at NSF that supported both research and outreach to promote women and minorities interest in STEM fields, but also to a dramatic spurt in the number of publications on the topic that has continued to grow at exponential rates since 2000. The meta-synthesis of the literature presented in this article demonstrates that since 2000 there has been a considerable interest in a wide variety of disciplinary venues in issues related to gender and STEM. While a large number of these have appeared in gender-focused journals, such as *JWMSE*, articles are widely dispersed across a variety of disciplinary venues. There is little redundancy among the names that appear as authors on the list of publications. The variety of journals and authors publishing articles suggests that not only has there been a good deal of energy devoted to issues related to gender and STEM over the last twenty years, but also that a wide audience has been involved. Given the size and variety of the body of literature and its wide dispersal across publication venues, authors restricting their literature reviews to familiar publication venues in a single discipline will not benefit from lessons learned about best practices in other STEM disciplines outside of their field.

The presence of a large and ever growing body of publications that are now largely available through traditional electronic searchers or by accessing the Women and

STEM Knowledge Center is a tremendous step forward, but not the entirety of an infrastructure for a specialized, cross-disciplinary topic like gender and STEM. Features of a well-built infrastructure have generally been fueled by support from external funding from programs at NSF, like GSE. This kind of infrastructure makes available synthetic pieces that summarize trends in findings from both research and practice. Evidence of this kind of infrastructure includes initiatives like Assessing Women and Men in Engineering (AWE) (Center for the Advancement of Scholarship on Engineering Education of the National Academy of Engineering: Http://www.engr.psu.edu/AWE/ARPresources.aspx). This project produced succinct and thoughtful literature summaries on key topics that are readily accessible to the public. It also includes a GSE funded initiative, the National Alliance for Partnerships in Equity (NAPE) that, among other services, provides research reports about promising practices (http://www.napequity.org/about-us/). It also includes an even newer entry to the field, the StratEGIC Toolkit. This is a portal that provides summaries of lessons learned and best practices gleaned from ADVANCE projects for institutional transformation (http://www.colorado.edu/eer/research/strategic.html).The Toolkit highlights 13 of the most frequently used change strategies and summarizes several models that have been used successfully at different ADVANCE institutions. Academics setting out to build a research agenda can save considerable time and resources and avoid redundancy by looking for synthetic reviews and tapping into the rapidly expanding infrastructure that is growing up around the topic of gender and STEM. The synergy of the infrastructure would be enhanced significantly through future initiatives that seek to link knowledge repositories in the U.S. with those in other countries.

The size of the body of literature about gender and STEM is at a point that there is growing need for systematic cross-disciplinary reviews. Systematic reviews or research synthesis pool or aggregate the results of empirical research about a single type of intervention executed in multiple settings and that consider how the lessons learned vary by population and setting. To further contribute to the evidence base for the practice, this kind of systematic review would have to address the generalizability of an intervention both within the U.S. and cross-culturally by more fully exploring contextual and cultural factors that promote and impede the targeted outcomes. To promote the continued development of practices derived from a foundational grounding and evidence, it is imperative that such compilations establish guidelines that distinguish between recommendations for practice or future research that derive from data that support it, from other persuasive recommendations that are intuitively compelling but more expansive than the data or analysis support.

While aspects of the infrastructure that facilitate the dissemination of research on gender and STEM have continued to expand, the field can still be characterized as immature. One justification for this label is that there is a lack of consensus about theoretical explanations for the continued under-representation of women in certain STEM fields that may be an additional by-product of the lack of opportunities for dialogue across disciplinary areas within STEM. Further work is needed through systematic cross-disciplinary reviews of the literature to catalog the root causes that are implicitly or explicitly attributed to this continued under-representation of

women in some fields and to consider how these may vary by context and field. Tracing differences in assumptions about the root causes, implicitly or explicitly articulated in publications, may help to explain why some disciplines like medicine, math, chemistry, and biology have been effective in increasing the recruitment and retention of women while others have not.

REFERENCES

American Educational Research Association (AERA). (2006). Standards for Reporting on Empirical Social Science Research in AERA Publications. *Educational Researcher*, *25* (*6*), 33-40. *doi:10.3102/0013189X035006033*

Andrews, R. & Harlen, W. (2006). Issues in synthesizing research in education. *Educational Research*, *48*(*3*), 287-299.

Beach, K. D., Becker, B. J. & Kennedy, J. M. (2007). Constructing Conclusions, In C. F. Conrad and R. C. Serlin, Eds., *The SAGE Handbook for Research in Education: Engaging Ideas and Enriching Inquiry*, Thousand Oaks, CA:SAGE Publishers, 493-510.

Caprile, M., Addis, E., Castano, C., Linge, I., Larios, M., Moulders, D. & Vazquez-Cuperio, S. (2012). Meta-analysis of gender and science research – Synthesis report. Luxembourg: European Union, Directorate-General for Research and Innovation. Accessed 19 February 2015 from: http://ec.europa.eu/research/science-socieity/document_library/pdf_06/meta-analysis-of-gender-and-science-research-synthesis-report.pdf.

Ceci, S. J. & Williams, W. M. (2010). Sex differences in math-intensive fields. *Current Directions in Psychological Science, 19* (*5*), 275-279.

Creamer, E. G. (1994). Gender and publications in core higher education journals. *Journal of College Student Development, 35*, 35-39.

Darke, K., Clewell, B. & Sevo, R. (2002). Meeting the Challenge: The Impact of the National Science Foundation's Program for Women and Girls. *Journal of Women and Minorities in Science and Engineering, 8*, 285-303.

Davies, P. (1999). What is Evidence-based Education? *British Journal of Educational Studies,* 47(2), 108-121.

Dellinger A.B. & Leech, N. (2007) Toward a Unified Validation Framework in Mixed Methods Research. *Journal of Mixed Methods Research, 1*(*4*), 309-332.

DuBois, E. C., Kelly, G. P., Kennedy, E. L., Korsmeyer, C. W. & Robinson, L. S. (1985). *Feminist scholarship: Kindling in the Groves of Academe*. Chicago: University of Illinois Press.

Eisenhart, M. & Towne, L. (2003). Contestation and Change in National Policy on 'Scientifically Based' Education Research. *Educational Researcher, 32*(*7*), 31-38.

European Research Council. (2013). On the Way to the Top: Providing Equal Opportunities for Men and Women in Science and Technology. Retrieved from http://erc.europa.eu/sites/default/files/content/pages/pdf/ERC_gender_workshop_Dec2013_final_summary.pdf March 29, 2015.

Fox, M. F., Sonnert, G., Brown, H., Kim, B., Nikiforova, I. & Willis, H. (2012). EAGER: The Transmission Zone Between Producers and Consumers of

Knowledge About Women in Science and Engineering.Poster presentation at the annual meeting of the Division of Human Resources at the National Science Foundation.

Hsieh, H. & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research, 15*(*9*), 1277-1288.

Lockheed, M. E. & Stein, S. L. (1980). The Status of Women's Research in Educational Publications. *Educational Researcher, 9*(*2*), 11-15.

Mutcheson, R. B., Sutherland, M. & Creamer, E. G. (2013). Poster session: Qualities of exemplary practice-oriented STEM publications. Poster Presentation at the 2013 CIDER Conference. Blacksburg, VA.

Rosser, S. V. & Lane, E. O. (2002). A History of Funding for the Women's Programs at the National Science Foundation: From Individual POWRE Approaches to the Advance of Institutional Approaches. *Journal of Women and Minorities in Science and Engineering*, *8*, 327-346.

Russ, J. (1983). *How to Suppress Women's Writing*. Austin, TX: University of Texas Press.

Sandelowski, M. Voils C. & Barroso, J. (2006). Defining and designing mixed research synthesis studies. *Research in Schools, 13* (*1*), 29-40.

Slavin, R. E. (2002). Evidence-based Education Policies: Transforming Educational Practice and Research. *Educational Researcher, 31*(*15*), 15-21. doi**:** 10.3102/0013189X031007015.

Stricker, G. (2003). Evidence-based Practice: The Wave of the Past. *The Counseling Psychologist, 31*(*5*), 546-554.

Tracking Trends in Gender and STEM Publications (TTGSP). Women and STEM Knowledge Center. Retrieved from: http://www.wskc.org/tracking-trends-in-gender-stem-pubs.

Appendix 1

Evaluation Criteria for Coding the Foundational Element of Practice-Oriented Articles

Evaluation Criteria	Scale Value	Ratings
References Supporting the Practice	0	No references
	1	One reference
	2	2-3 references
	3	More than 3 references
Support for Effectiveness of the Practice	4	Documentation that the decision to implement was based on data.
Scale-Up of a Pilot Study	5	Documentation provided that the activity was a scale-up of a pilot study.

Theoretical Framework	6	Explicit references to a theoretical framework were included in the article.

Acknowledgments
This research was supported with funds from the National Science Foundation (GSE 0832913).
Jane Langeman was instrumental in the development of the database reported in this article.